DEVELOPMENT AND TESTING OF THE RIGIDIZABLE INFLATABLE GET-AWAY-SPECIAL EXPERIMENT

THESIS

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Abstract

The purpose of this research project is to develop the Rigidizable Inflatable Get-Away-Special Experiment (RIGEX) from a computer-based model into a space-qualified prototype. Past research projects have developed RIGEX's command and control, structural analysis, and integration with the orbiter. This thesis details the organization, assembly, and test planning for the RIGEX protoflight model.

Strict requirements imposed by the National Aeronautics and Space Administration (NASA) must be fulfilled for any payload to travel into space. Based on the requirements set forth by NASA documentation, this thesis establishes appropriate assembly procedures for the construction of a space payload. Detailed design changes are described, as well as any problems encountered during assembly. Various lessons learned throughout the course of this project are discussed.

To my Family and Friends

Acknowledgments

I would like to express my sincere appreciation to my faculty advisor, Dr. Richard Cobb, for his guidance and support throughout the course of this thesis effort. The insight and experience was certainly appreciated. I am also indebted to the many engineers, technicians, machinists, contractors, and vendors who spent their valuable time helping me overcome the numerous setbacks and challenges presented by this project.

I would like to personally thank Mr. Wilber Lacy, Mr. John Hixenbaugh, Mr. Chris Zickefoose, Mr. Barry Page and the boss, Mr. Jay Anderson for their never-ending willingness to drop what they're doing and help. I would like to thank Mr. Jason "Turk" Vangel and Mr. Jan LeValley for their patience and persistence. I would like to thank Mr. Carson Taylor, Mr. Scott Ritterhouse, Maj. Matthew Budde, USAF, and Ms. Theresa Schaeffer at STP for their knowledgeable emails and polite recommendations. I would like to thank Mr. Dan Pohlabel at Dysinger, Mr. Mike Conklin at Westwood Finishing, Mr. Dwayne Conley at TechMetals, and Mr. Brian Clark at Swagelok for their genuine support and friendly assistance. I appreciate the help I have received from my classmates, ENS Zach Miller, USN, Capt. Jeremy Owens, USAF, and 2ndLt Anna Gunn-Golkin, USAF. I would also like to thank my gear-head friends that have provided me with the technical experience needed to assemble a complex project.

Finally, I would like to thank my family for their love and encouragement.

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List of Symbols and Abbreviations

Symbol or Abbreviation – Definition

Al – Aluminum

AFIT – Air Force Institute of Technology

C – Celsius

CAD – Computer Aided Design

CAPE – Canister for All Payload Ejections

CDR – Critical Design Review

CHUG – CAPE Hardware Users Guide

CRES – Corrosion Resistant Stainless Steel

DoD – Department of Defense

FEA – Finite Element Analysis

FEM – Finite Element Model

GAS – Get-Away-Special

GSE – Ground Support Equipment

IVT – Interface Verification Test

JSC – Johnson Space Center

KSC – Kennedy Space Center

LED – Light Emitting Diode

MEFL – Maximum Expected Flight Level

NAS – National Aerospace Standard

NASA – National Aeronautics and Space Administration

PZT – Lead Zirconate Titanate (Piezoelectric Transducer Patch)

RIGEX – Rigidizable Inflatable Get-Away-Special Experiment

STP – Space Test Program

SVP – Structural Verification Plan

USAF – United States Air Force

USN – United States Navy

DEVELOPMENT AND TESTING OF THE RIGIDIZABLE INFLATABLE GET-AWAY-SPECIAL EXPERIMENT

I. Introduction

In the modern era of warfare, intelligence reigns supreme. Much of the intelligence needed can be gathered through space-based techniques. The Department of Defense's (DoD's) ability to collect intelligence on an adversary rests on the shoulders of advanced surveillance systems. Therefore, the need for remote sensing and surveillance systems is paramount. For this technology to exist, the DoD requires large collectors in space. Unfortunately, launching large payloads into space is extremely challenging. In order to enable large structures to be launched into space while keeping within current launch parameters, inflatable structures are developed. To this end, the Air Force Institute of Technology (AFIT) has been developing a space shuttle demonstration called the Rigidizable Inflatable Get-Away Special Experiment (RIGEX).

RIGEX is a self-contained experiment to test the deployment of rigidizable inflatable tubes in the space environment. While other inflatable systems have been launched in space, this experiment is the first to test a rigidizable inflatable material in

space. Since it is rigidizable, it requires no additional gas pressure to maintain structural integrity after inflation. In essence, RIGEX is demonstrating the viability of 'growing.'

1.1 Past RIGEX Work

Since its inception as a student-based project at AFIT in 2001, the RIGEX program has developed from a grand idea to an impressive space prototype. Previous RIGEX work can be referenced through past thesis projects. This thesis is based on previous students' research, design, and testing. Through the extensive efforts of past students, the RIGEX program has witnessed a Preliminary Design Review (PDR), Critical Design Review (CDR), and Phase II Safety Review, all through the National Aeronautics and Space Administration (NASA). The following section is a brief description of each thesis' contribution towards sending RIGEX to space.

1.1.1 DiSebastian (4)

DiSebastian's work established RIGEX's mission statement, objectives, requirements and constraints. He created a preliminary parts list and experimental configuration for RIGEX based on a Get-Away Special (GAS) Canister used by the space shuttle program shown below in Figure 1.

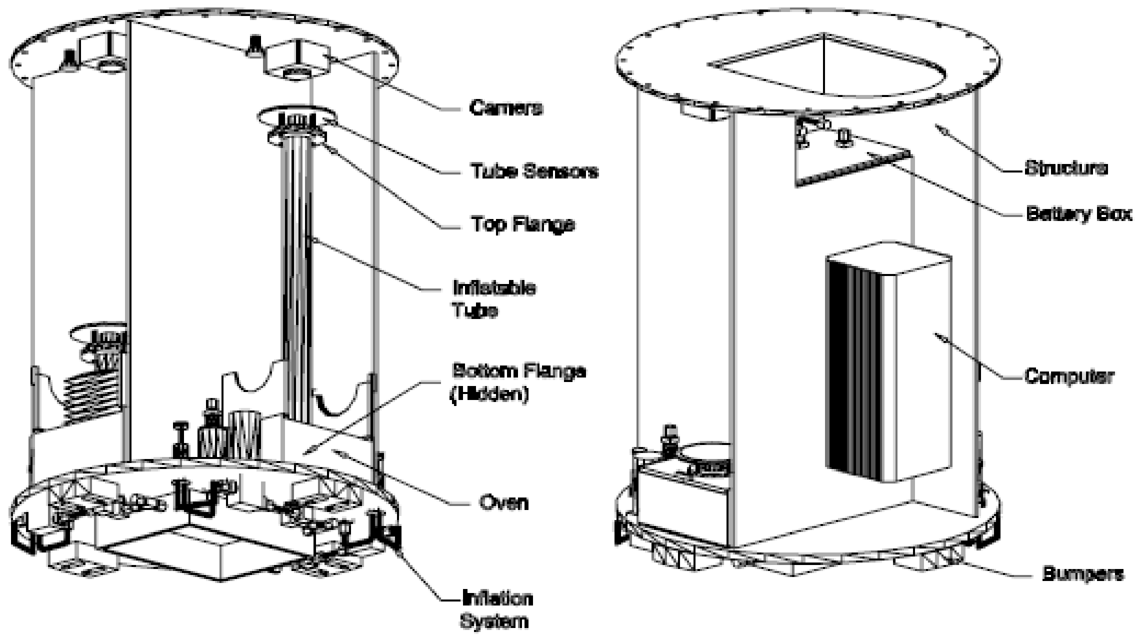


Figure 1: DiSebastian's Preliminary Design (4).

1.1.2 Single (18)

Single conducted extensive ground deployment testing on the rigidizable inflatable tubes. His work established that ground test data should be used to compare with space flight test data in order to analyze the tubes' space performance.

1.1.3 Thomas L. Philley (17)

Using DiSebastian's preliminary design, Philley built and tested a prototype model of RIGEX inside AFIT's old vacuum chamber. Philley's work documented the deployment of the tubes in a variety of configurations. Figure 2 below shows one of Philley's experimental test configurations.

Figure 2: Philley's Test Configuration (17).

1.1.4 Holstein (8)

Holstein performed numerous iterations of Finite Element Analysis (FEA) on both the tubes and the prototype structure. Holstein's work provided useful data towards determining the natural frequencies of the RIGEX structure. An example of his ABAQUS finite element model (FEM) for the tube and the quarter structure can be seen in Figure 3.

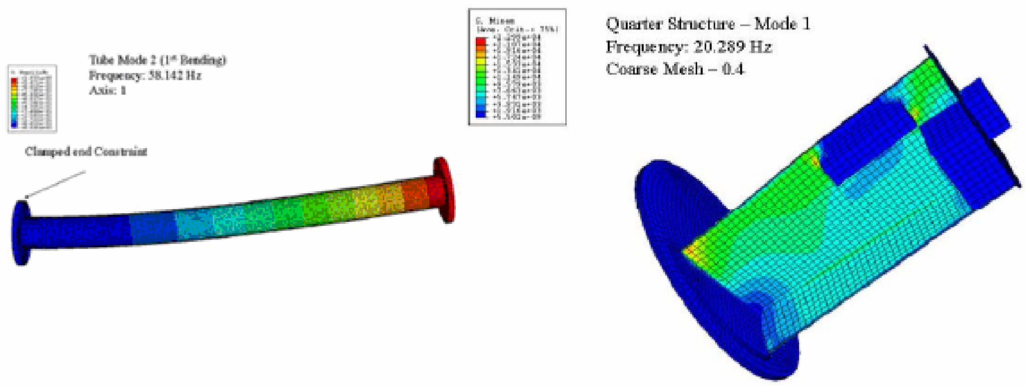


Figure 3: Holestein's ABAQUS Finite Element Model (8).

1.1.5 Lindemuth (9)

Working with a quarter-structure of the preliminary design, Lundemuth tested and established a heating profile for the tubes used in the experiment. Based on his conclusions, Lundemuth created design modifications to the inflation system so that the system was more robust. Lindemuth's final design for the heater boxes can be seen below in Figure 4.

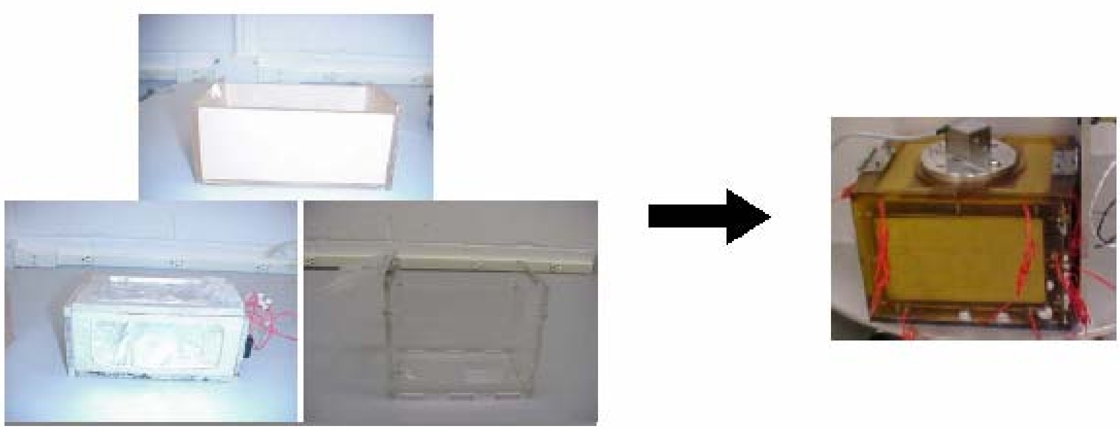


Figure 4: Preliminary Heater Boxes and Lindemuth's Final Heater Box Design (9).

1.1.6 Moody (11)

Moody created the computer code to be used for ground testing and flight testing data acquisition. Moody's designs used a battery-powered computer and power distribution system to allow RIGEX to operate autonomously. A schematic of Moody's prototype computer is shown below in Figure 5.

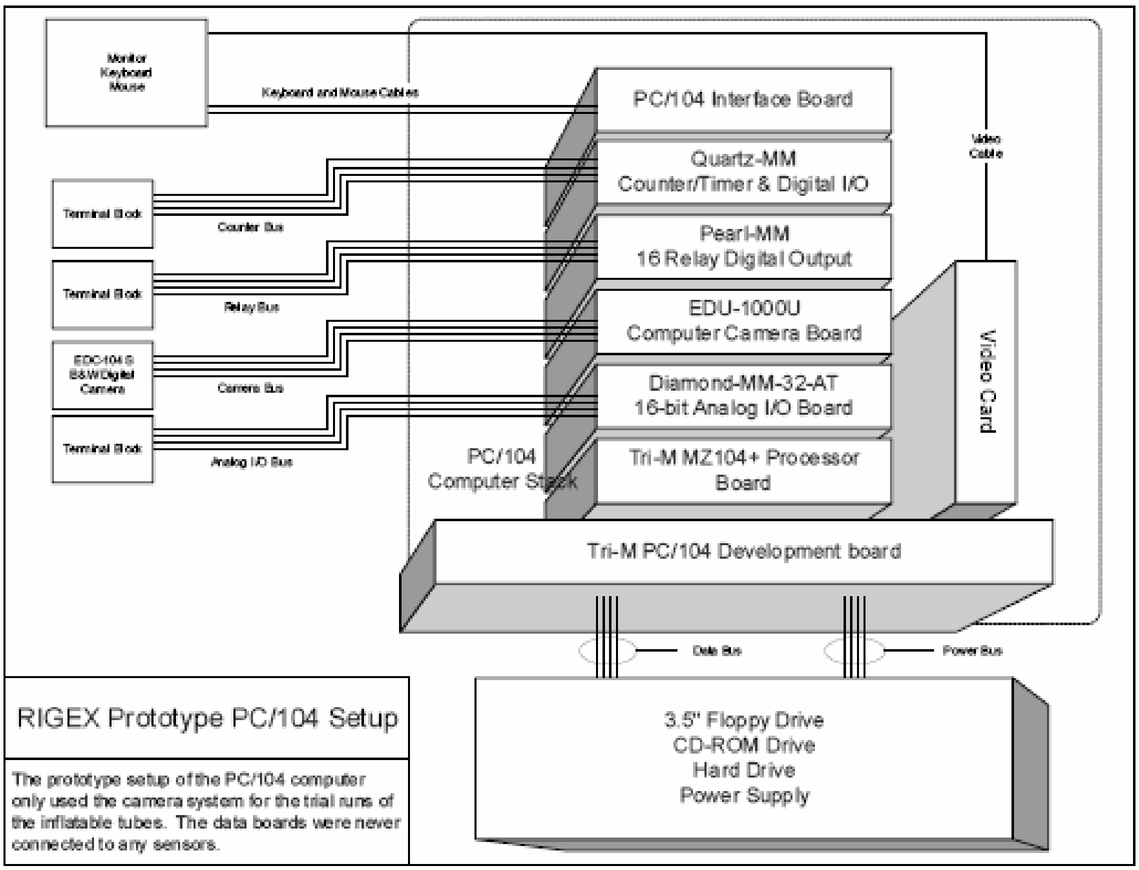


Figure 5: Moody's Prototype Computer (11).

1.1.7 Moeller (10)

Moeller's research witnessed a significant change to RIGEX's flight configuration. No longer would RIGEX fly in a GAS canister. Instead, RIGEX would

use the Canister for All Payload Experiments (CAPE) for transportation into space. Moeller's work attempted to deal with a variety of complications associated with NASA's switch to the CAPE canister.

1.1.8 Helms (7)

Helms explored the vibration response characteristics of both the RIGEX prototype and the oven assembly used for heating the tubes, as shown in Figure 6. Her work included taking steps towards the fulfillment of NASA's requirements for producing proper documentation for space payloads.

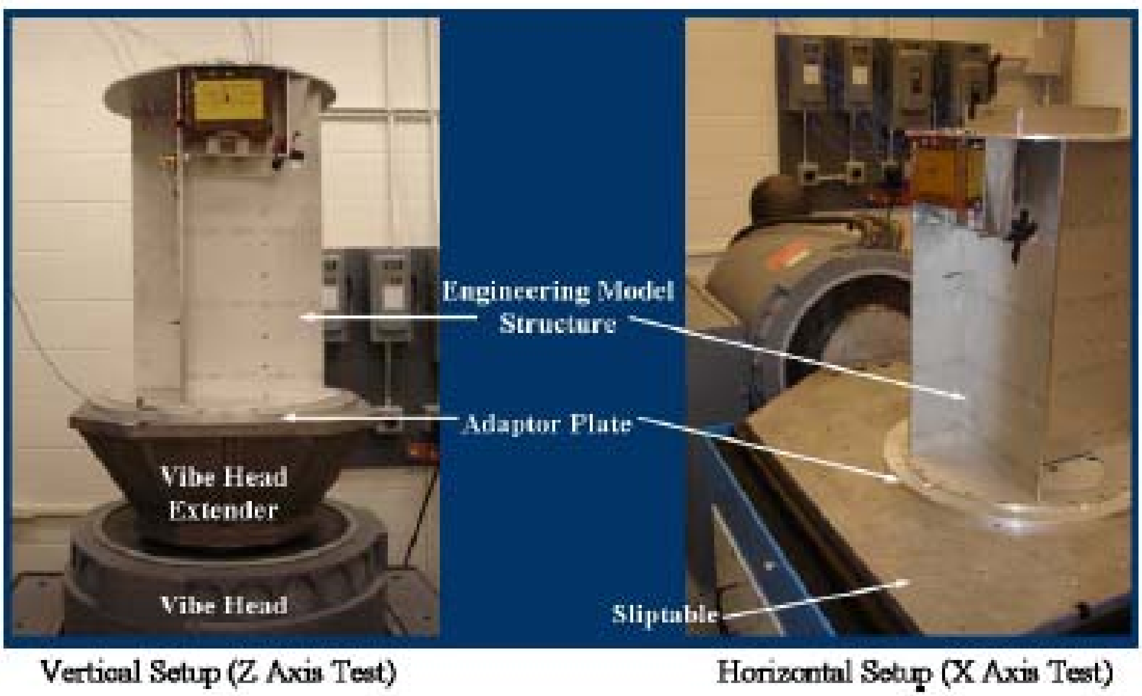


Figure 6: Helms' Vibration Test Configurations (7).

1.1.9 Goodwin (5)

Using SolidWorks software, Goodwin generated a detailed computer model of the RIGEX structure and its associated components, shown in Figure 7. This model included numerous design changes so that RIGEX would accommodate its new canister and power source.

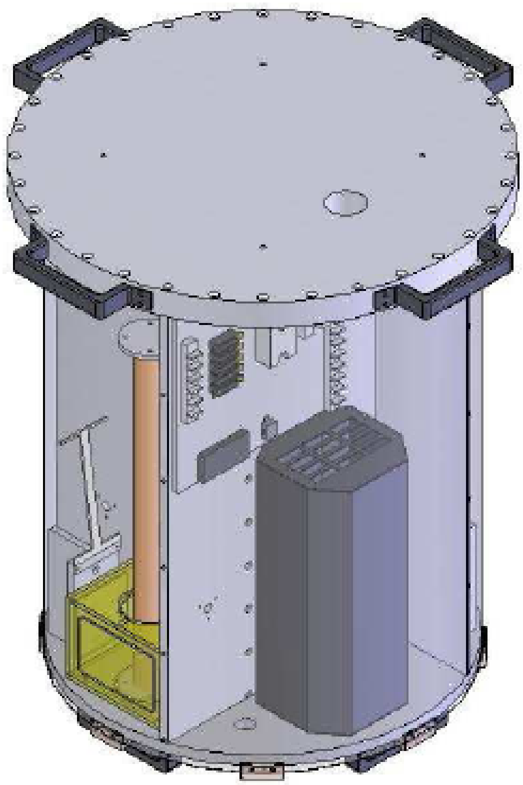


Figure 7: Goodwin's SolidWorks Model (5).

1.1.10 Gunn-Golkin (6)

Gunn-Golkin developed the final FE model to be used for the structural analysis of RIGEX. Gunn-Golkin made the appropriate modifications to RIGEX's design in an attempt to satisfy all of NASA's requirements for the structural integrity of space payloads. Gunn-Golkin's work resulted in a complete set of design drawings to include a

wiring diagram for the fabrication and assembly of the RIGEX protoflight model. Her updated SolidWorks model can be seen in the figure below.

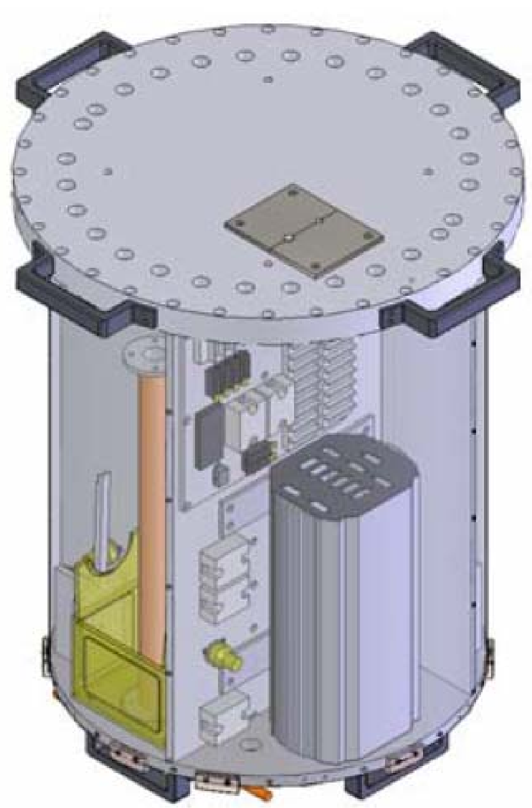


Figure 8: Gunn-Golkin's SolidWorks Model (6).

1.2 Summary and Thesis Outline

This thesis continues the development of the RIGEX protoflight model in hopes of achieving acceptance by NASA and ultimately space flight. This thesis documents several aspects of the progression from design to flight. Chapter II covers the NASA requirements for a space payload's documentation tree. The documentation tree is an

approved set of documents that includes procedures and drawings to validate a space payload's worthiness for space flight. Chapter III discusses several NASA requirements and describes how the RIGEX team fulfilled each requirement. Chapter IV documents the construction of the RIGEX protoflight model. Problems during construction are identified and solutions are explained. Chapter V discusses AFIT's plan for space qualification of the RIGEX structure, including thermal vacuum testing and vibration testing. Lastly, Chapter VI of this thesis discusses the future of the RIGEX program. Additionally, the last chapter reports on some of the lessons learned during the course of this thesis project.

II. Requirements Background

Having established the motivation and history of the RIGEX project, this chapter will discuss the requirements set forth by NASA concerning proper documentation for space payloads traveling in the orbiter. More specifically, this chapter will identify the requirements for all payloads traveling inside the Canister for All Payload Ejections (CAPE).

2.1 NASA Documentation Tree

A critical portion of integrating a space payload into NASA's shuttle manifest revolves around the creation of a thorough documentation tree. This documentation tree consists of drawings, procedures, and test reports that validate a payload's worthiness for space flight. RIGEX must satisfy all requirements set forth by NASA regulations. In addition, RIGEX must satisfy all requirements set forth by the Space Test Program (STP), the owners of CAPE, because RIGEX will fly inside of CAPE. Fortunately, STP and NASA requirements state the same diretives. Therefore, if RIGEX fulfills the STP requirements, it will also fulfill the NASA requirements (1). Figure 9 illustrates the breakdown of each branch of the documentation tree.

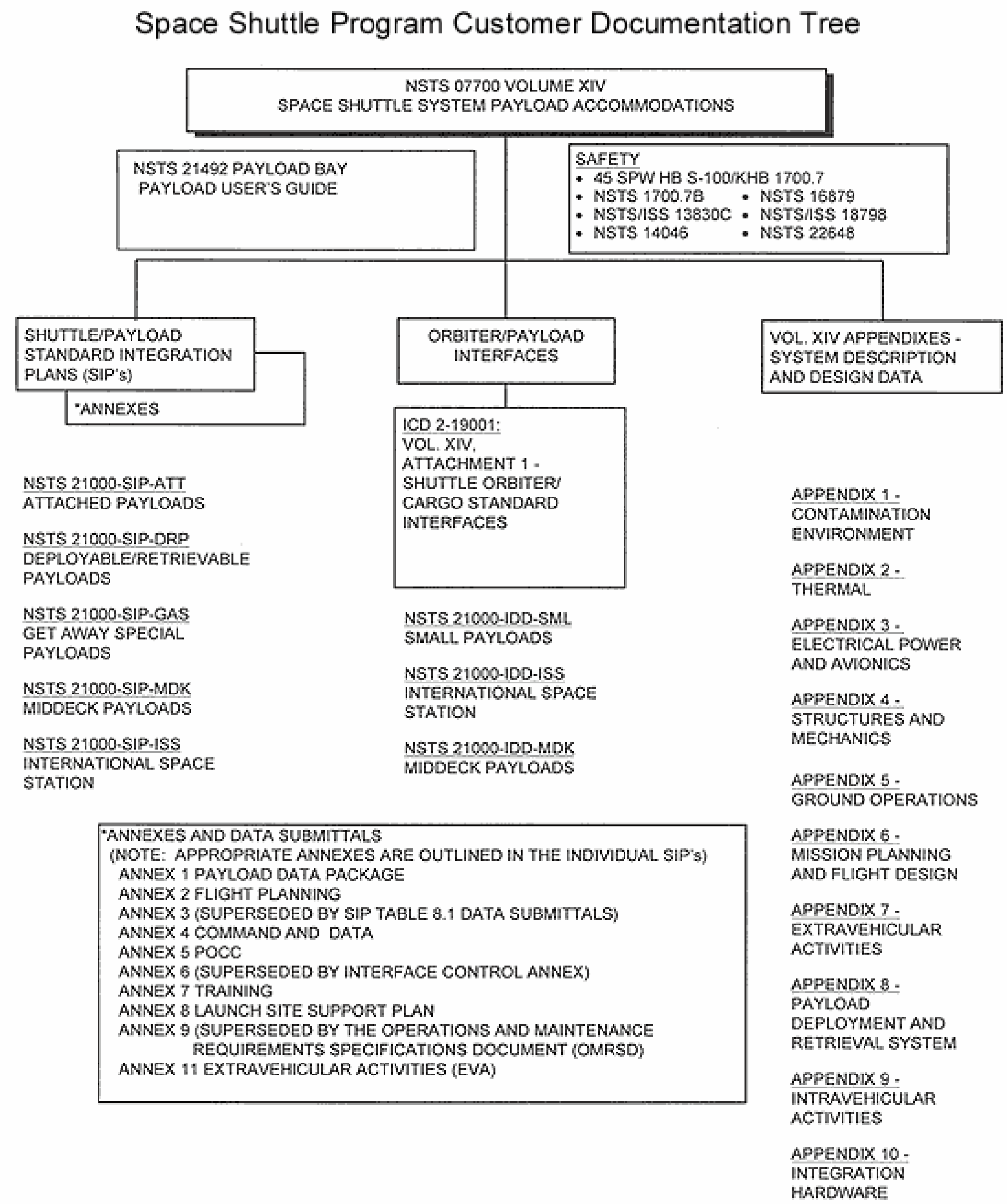


Figure 9: NASA Documentation Tree Schematic (14).

To determine the requirements of using CAPE, the RIGEX team referenced the *CAPE Hardware Users Guide* (CHUG) (3). This document is maintained by DoD payload integration contractors. Its purpose is "to identify specific interfaces and other

accommodations available on the USAF Space Test Program (STP) Canister for All Payload Ejection (CAPE) and establish guidelines and requirements for the payloads intending to fly within it" (3). RIGEX is considered a *Canister Lid* payload by the CHUG because RIGEX's CAPE Mounting Plate will act as both a canister lid for CAPE and a top plate for the RIGEX experiment. Weight requirements set forth by the CHUG require a payload to weigh no more than 350 pounds and have a CG location no less than 25 inches below the CAPE lid in the center of its diameter (3). Such requirements were taken into account early in the design phase of RIGEX. The CHUG also provides specific environmental requirements to include thermal, vibration, depressurization/pressurization, and electromagnetic compatibility requirements. The CHUG references other NASA documentation to provide specific details on testing envelopes and guidelines.

2.2 Requirements Summary

Compiling all elements of NASA's documentation tree is a daunting task. Fortunately for the RIGEX team, the engineers at STP retain authority over all aspects of the RIGEX/CAPE documentation tree. The role of the RIGEX team in the documentation process is to comply with STP's recommendations and provide specifics on RIGEX's design, assembly, and component acquisition. This enables STP to proceed with the test planning and coordination with NASA for flight qualification of RIGEX.

III. Preparation for Assembly

Meeting the requirements set forth by NASA for space travel requires a great deal of organization and planning. This chapter discusses several different organizational and groundwork techniques used by the RIGEX team to prepare for the construction of the RIGEX protoflight model.

3.1 Contamination and Corrosion Protection

NASA document NSTS 1700.7B sets forth specific standards regarding the treatment of metallic surfaces flying in space (13). According to this document, payloads must be grounded properly and protected from corrosion (13). Several metal finishing techniques enable the requirements of NASA document NSTS 1700.7B to be fulfilled. To defend against contamination, corrosion, and poor conductivity of the RIGEX structure, three different metal treatment methods were used: alodining, anodizing, and painting.

The RIGEX primary structure is made of 6061-T6 Al. Various secondary structural components are also made of 6061-T6 Al. When assembled, the RIGEX structure is designed and expected to be electrically grounded. A single ground lug attached to the Large Computer Rib provides a solid connection for the electrical components' grounding. In order to facilitate proper grounding throughout the entire structure, all structural pieces were treated with a chromate conversion coating, or

alodine coating. Alodine coating of RIGEX's aluminum surfaces was done by TechMetals of Dayton, OH in accordance with MIL-C-5541 Class I A. TechMetals uses a series of cleaning detergents such as sodium hydroxide and nitric acid to cleanse bare aluminum surfaces of oils, grease, and other potential contaminants. Alodine, a trade name, is a chemical film. The alodining process takes several minutes and consists of dipping clean, bare aluminum into a tank filled with a hexavalent chromium solution for 90 seconds. The metal is rinsed between each step in the process, and then dried with dry compressed air. The alodine coating provides several important features to the bare aluminum. An alodine coating provides an excellent base layer for paint applications. An alodine coating also provides some level of protection from corrosion by the environment. Additionally, an alodine coating between two mating pieces of aluminum promotes good conductivity between the two pieces (2).

Although alodine coating provides some level of corrosion protection, it is not a particularly robust coating. Alodine coating can be removed by hard rubbing with a cloth or even a finger. Alodine coating does a poor job holding up in metal-on-metal rubbing applications. Rather than relying on alodine coating to provide corrosion protection, all aluminum surfaces were anodized in accordance with MIL-A-8625 Rev. F, Type II, Class II, BLACK. Anodizing is an electrochemical two-step metal treatment process that refinishes the surface of the aluminum with an aluminum oxide barrier. It is important to note that no additional metal is added to the surface of the aluminum during the anodizing process. Anodizing is a conversion coating, not a plating process. Anodizing is accomplished by first dipping a piece of aluminum into a solution of sulfuric acid that

is electrically charged with an external power source. With the positive side of the voltage source connected to the aluminum and the negative side submerged into the sulfuric acid solution, oxygen from the solution reacts with the aluminum and forms a thin layer of aluminum oxide. This aluminum oxide coating penetrates the surface of the aluminum approximately five thousandths of an inch. The aluminum oxide layer is then dipped into organic dyes which absorb into the porous anodic coating. Finally, the part is sealed with nickel acetate at 165°C for approximately 20 minutes. The nickel provides the corrosion protection while sealing any pores in the material (2). The AFIT team employed TechMetals to apply black anodizing to the majority of RIGEX's exposed surfaces.

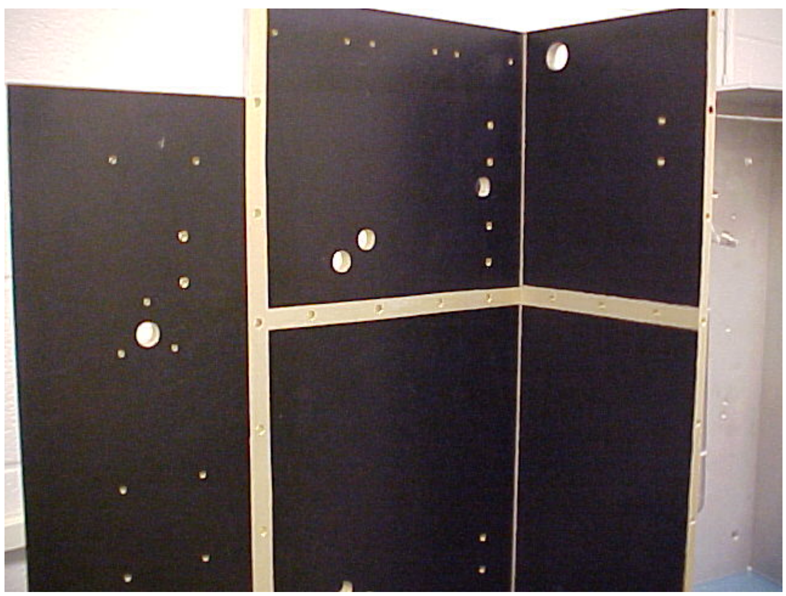


Figure 10: Example of Alodine and Anodize Coating.

In Figure 10, the lighter gold-colored areas show the alodine coating. These lighter areas highlight where metal-on-metal contact will occur. The black areas show the anodized surfaces. These surfaces are able to withstand handling and light scratching, both

guaranteed byproducts of the transportation and assembly of the RIGEX structure. Specific instructions on how each component of RIGEX was anodized can be viewed in Appendix H. The goal of these specific instructions was to maximize the amount of alodine-to-alodine contact between mating surfaces in order to promote proper grounding. At the same time, these directions maximized the amount of corrosion protection from black anodizing.

The only component on the RIGEX assembly that will be painted for space flight is the CAPE mounting plate. The CAPE mounting plate requires a different type of metal protection since it will be directly exposed to the space environment. STP provided Aeroglaze paint and primer to treat the CAPE mounting plate for flight. Before being painted, the CAPE mounting plate received an alodine coating to ensure electrical conductivity with the rest of the structure and to provide a good base layer for the primer and paint. STP provided Aeroglaze paint and primer, manufactured by LORD, Inc. to treat the CAPE mounting plate for flight. The primer used on the CAPE mounting plate is Aeroglaze 9929, and the paint is Aeroglaze A276. Aeroglaze A276 paint is used in a variety of space applications for a variety of reasons. A276 paint is easy to apply, inexpensive to procure, durable, and exhibits low out-gassing at extreme temperatures and vacuum conditions. The AFIT team employed Westwood Finishing Company of Trotwood, OH to prime and paint the CAPE mounting plate. Figures 11 and 12 illustrate how the CAPE mounting plate was painted by Westwood Finishing.

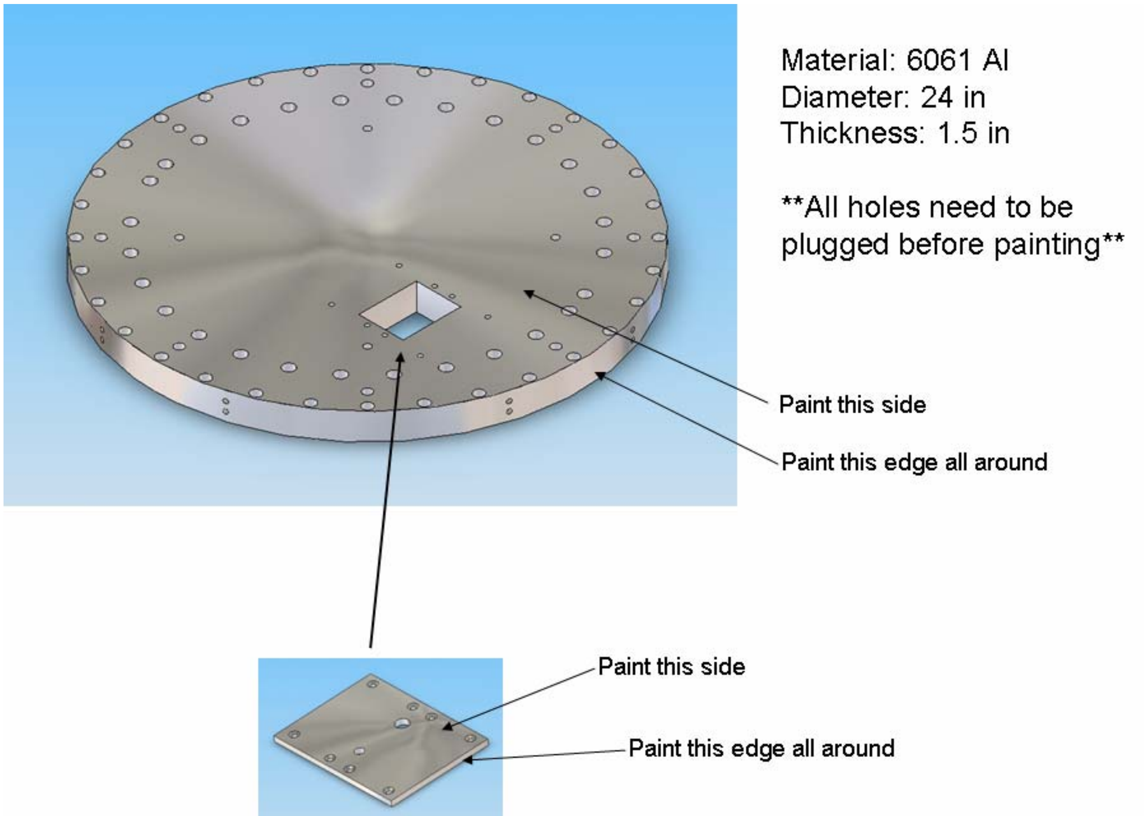
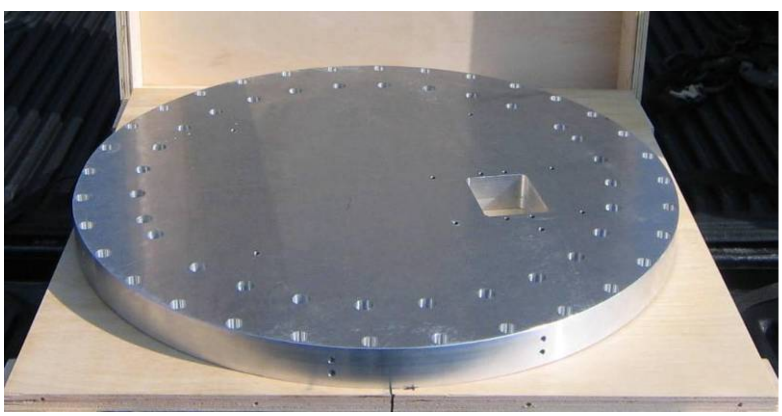
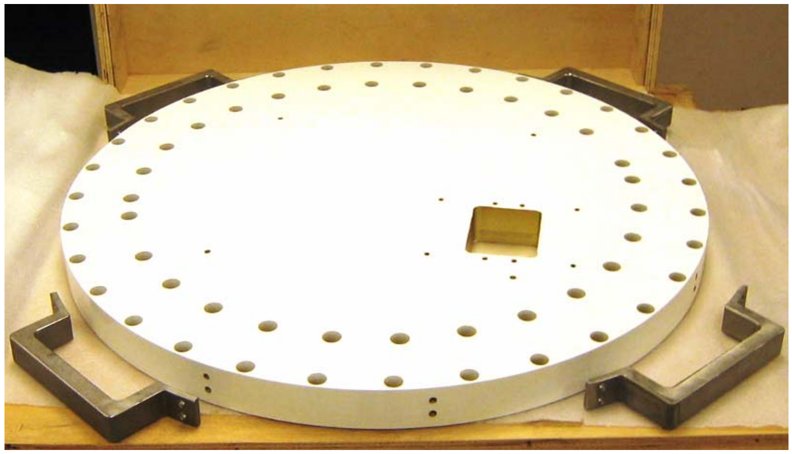


Figure 11: Painting Instructions.



(a)



(b)

Figure 12: CAPE Mounting Plate (a) Before and (b) After Painting.

3.2 Assigning Part Numbers to RIGEX

Throughout the course of the project, RIGEX has been referred to only by the acronym RIGEX. Various sub-assemblies have been referred to by their own title, such as the Oven Assembly or Computer Assembly. RIGEX, though, has been left to describe some end state of the entire experiment. Unfortunately, as RIGEX grows into a prototype with numerous configurations, the name RIGEX no longer describes the experiment with enough detail. According to standard NASA acceptance practices for prototype testing and deployment, different configurations of flight hardware require some type of naming system. Using a methodical and logical naming system allows for each different configuration of RIGEX to be described as a different part. There is no specified way to name different configurations, but a sensible approach would be to begin with a common root, RIGEX, and add to it accordingly. In doing so, each additional RIGEX configuration number provides a greater amount of detail about the

particular configuration. This increased amount of detail alleviates confusion because different parties can easily reference the drawing number and immediately know how RIGEX is configured. The drawing number and the part number are typically the same. However, to distinguish between a drawing number and an actual part number, a “-D” is added to the drawing number and a “-P is added to the part number. For example, RIGEX-WAVE1-D would be a drawing label, and RIGEX-WAVE1-P would signify the actual part number of real hardware. Below is an example of a drawing identification block.

	AIR FORCE INSTITUTE OF TECHNOLOGY				
	WAVE #1 SUBASSEMBLY				
	SIZE A	FSCM NO		DWG NO RIGEX-WAVE1	REV A
	SCALE	1:1	B. O’Neal	SHEET	1 OF 1

Figure 13: Example of RIGEX Drawing Number Identification Block.

For this project, the RIGEX assembly was divided into three separate *waves*. Each wave is a set of assembly steps. As such, the end of each wave yielded a different RIGEX drawing number. Of course, the all-inclusive computer model of RIGEX is not how the experiment will appear for space flight, nor is it how the project will be shipped and tested. In conjunction with the other members of the RIGEX team, all of the different configurations of RIGEX were determined. First, RIGEX needed to be assembled. With three different waves, RIGEX was assigned three different drawing numbers: RIGEX-WAVE1-D, RIGEX-WAVE2-D, and RIGEX-WAVE3-D. The end of wave #3 leaves

RIGEX with all structural pieces and flight hardware pieces installed. However, in order to distinguish between test configuration and space flight configuration, more drawing numbers needed to be assigned. For the space flight drawing configuration, which includes all flight hardware, such as the real flight sub-Tg tubes, RIGEX was named RIGEX-FLT2008-D. For testing purposes, RIGEX will be configured exactly the same as the flight configuration except for the non-flight sub-Tg tubes. As such, RIGEX was named RIGEX-TST2007-D. These names were given in hopes of completing all testing in 2007 and achieving successful launch in 2008. These examples identify only a few of the many different RIGEX configurations. A complete list of the RIGEX part numbers is seen below in Table 1.

Table 1: RIGEX Configurations

Part Number	Configuration Description
RIGEX-WAVE1-P	Wave 1 Assembly Complete, main structure intact
RIGEX-WAVE2-P	Wave 2 Assembly Complete, main structure and various subassemblies
RIGEX-WAVE3-P	Wave 3 Assembly Complete
RIGEX-HAN2007-P	Wave 3 + lifting handles, feet
RIGEX-TST2007-P	Wave 3 + GSE
RIGEX-SHIP2007-P	Wave 3 without shroud, CAPE mounting plate

RIGEX-FLT2008	Wave 3 + flight tubes + flight cables

3.3 Torque Values during Assembly

Structural analysis performed by Gunn-Golkin in 2005-2006 was used to determine the size of fasteners needed to properly secure the primary and secondary structural elements of RIGEX together for flight (6). Using the results of Finite Element Analysis (FEA), Gunn-Golkin identified the size, location, and orientation of every bolt, washer, and nut to be used on the entire RIGEX structure. With the exception of the oven boxes, all components on RIGEX will be secured using National Aerospace Standard (NAS) fasteners. The structural integrity of the oven boxes was validated by Helms (7). An acceptance memorandum addressing the use of non-NAS fasteners for flight hardware can be seen in Appendix F.

NASA document NSTS/ISS 18798, Interpretation Letter MA2-00-057 requires that every threaded fastener use two separate and different locking mechanisms to prevent back-out of bolts during flight (12). One back-out prevention method used on every fastener is the applied torque. Applied torque can also be referred to as preload. The second back-out prevention technique used on RIGEX's fasteners includes such methods as using patch lock bolts, locking Heli-Coils, and locking nuts.

Running torque, applied torque, and total torque are three terms used to describe torque of a fastener. In NASA document MSFC-STD-486B, *Torque Limits for Standard, Threaded Fasteners*, torque values are tabulated for different bolt diameter sizes and different back-out prevention methods (16). Running torque refers to the torque experienced by the bolt as it is initially threaded into its mating threads. If a fastener has

patch lock applied, running torque is measured only when resistance is felt by the patch lock. For locking Heli-Coils and locking nuts, running torque is only measured when the fastener threads begin to engage the locking mechanism. The applied torque of a fastener is the most important quantity to be measured. Data provided by NASA document MSFC-STD-486B tabulates applied torque values (16). This torque value is a measure of the actual squeezing done between the fastener and the component being secured. The total torque value is the combination of the running and applied torques, that is,

$$\textit{Running Torque (inlbs)} + \textit{Applied Torque (inlbs)} = \textit{Total Torque (inlbs)} \qquad (1)$$

For RIGEX's assembly, each fastener is installed using an inch-pound or inch-ounce torque wrench. During actual assembly, only the running torque values and the total torque values are read off of the torque wrench gauge and recorded. The applied torque is then deduced from the running and total torque values. Figure 14 shows the three torque wrenches that were calibrated for use in the assembly of the RIGEX protoflight model.

Figure 14: Torque Wrenches for Construction.

The flow of documenting torque values went as follows: measure and record running torque, add desired applied torque, and then measure and record the total torque. While this may seem tedious, the actual process was easy to carry out and document. All of the torque values were recorded in the RIGEX assembly procedures, as shown in Appendices A, B, and C. Figure 15 is a picture of a torque wrench being used in the construction of RIGEX.

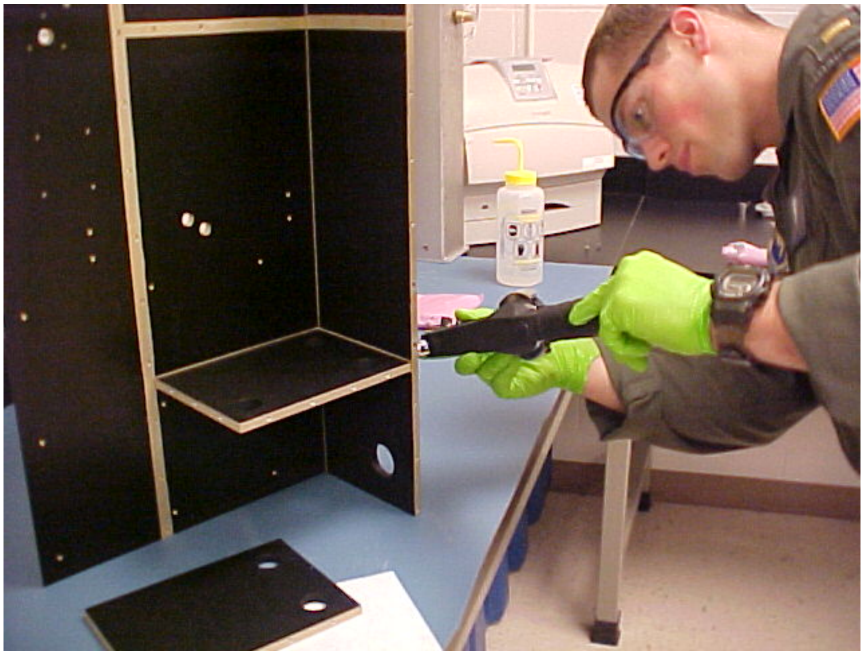


Figure 15: Torque Wrench in Action.

The main reason to have a maximum or total torque value specified is to raise it to everyone's attention if there is galling of the threads or cross-threading, for example. Smart installation would dictate that a technician stop applying torque before further damage is done, such as breaking the head off the screw or destroying the female threads. Both of these faults are much more difficult to fix than simply replacing a damaged screw. Additionally, in the bolt analysis, a maximum running torque was assumed for each fastener. If exceeded, there might be a case where a negative margin on stress occurs if the running torque is too high.

In most cases, it is not a serious problem if fasteners are installed with a running torque a few inch-pounds above the specified limit. In this case, one method recommended by the engineers at STP is to back the screw out and try it again. After cycling the locking patch once, the running torque typically drops significantly on the

second installation of that screw, which might bring it inside the specified range. The running torque will most likely drop further each time a patch on a screw or bolt is cycled. Eventually, it becomes necessary to replace a patch lock screw if installed too many times.

3.4 Chapter Summary

This chapter identifies AFIT's attempt to conform to the stringent requirements set forth by NASA documentation. Although problems were confronted, all potential issues were overcome with the help of STP engineers' recommendations. In instances where the AFIT team deviated from the exact design or letter of the law, the team was still able to fulfill the intent of each NASA requirement. Some of these deviations are discussed in greater detail in the next chapter of this thesis.

IV. Mechanical Assembly

Before space qualification testing of the RIGEX structure could take place, RIGEX needed to be assembled. Past thesis students have compiled a nearly complete materials inventory to be used in the assembly of RIGEX. This chapter describes the construction of the RIGEX protoflight model and the problems encountered during assembly.

4.1 Wave 1 Construction

Throughout the course of this thesis effort, the RIGEX project has evolved from a set of engineering drawings and a cabinet full of flight components into an actual protoflight model torqued, treated, and tested for space flight. Like many engineering projects, there have been numerous design changes and problems to overcome. All of these modifications have been properly documented through the use of a non-conformance log.

As soon as the AFIT machine shop finished fabrication of the main structural pieces of RIGEX, the RIGEX team readied the pieces for metal treatment. A fit check of the pieces was done as best as possible. Since the AFIT machine shop finished making the various components of RIGEX at different times, it was decided that the assembly would be split into three different waves. Wave 1 of the RIGEX assembly procedure describes the construction of the main RIGEX structure. Wave 2 of the RIGEX assembly

procedure describes the addition of various structural and experimental components. Wave 3 of the RIGEX assembly procedure describes the addition of all parts designed to be removable once installed. Mostly, this means that the components installed during Wave 3 are held in place with locking Heli-Coils, which are designed to accept fasteners multiple times.

Before the components necessary to complete Wave 1 were finished by the machine shop, a small mistake in the fabrication of three of the rib plates had to be corrected. This forced the RIGEX team to outsource the re-machining of these parts to Dysinger, Inc. of Dayton, OH. New aluminum was drop shipped to Dysinger's machine shop, and Dysinger machined three new ribs for RIGEX: the Large Rib, Large Computer Rib, and Small Rib without Pin-Puller. Once all parts required for Wave 1 assembly were machined correctly, the materials were taken to TechMetals to receive alodine and anodize coating. As soon as the AFIT team received the parts back from TechMetals, the team noticed that two of the rib plates received anodizing along their edges.

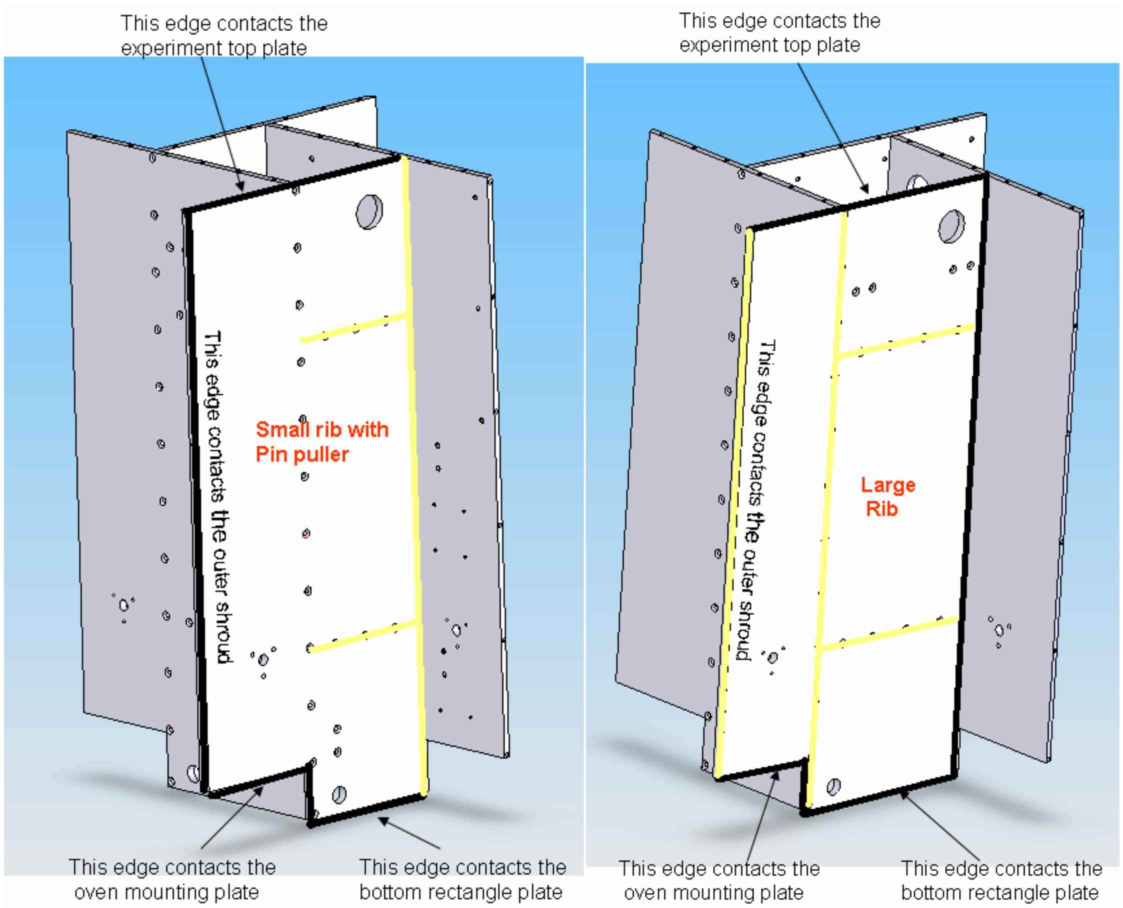


Figure 16: Anodizing Mistakes.

Both the Small Rib with Pin puller and the Large Rib were anodized incorrectly. Both the Large Rib and Small Rib with Pin puller maintain over a 16 square inch area of alodine-to-alodine contact with other pieces. In both cases, this contact area is divided between an adjacent rib and the inflation system mounting plates. All other rib interface areas have alodine-to-alodine contact. The dark black lines shown in Figure 16 were anodized by mistake. The yellow lines show an inner alodine-to-alodine surface. In a teleconference discussion, STP recommended that a resistance test be done to verify electrical conductivity between the ribs in question and the rest of the structure. These resistance tests were successful in proving that there was no loss of conductivity

throughout the structure due to the anodizing errors. Documentation of these resistance tests are in Appendix A.

Wave 1 of the RIGEX assembly was carried out in a relatively smooth fashion. One detail left unclear by the designers of RIGEX was the mounting of the three inflation system pressure vessels. 1/8” thick Viton was used to isolate the stainless steel pressure vessels from the aluminum inflation system mounting plates.

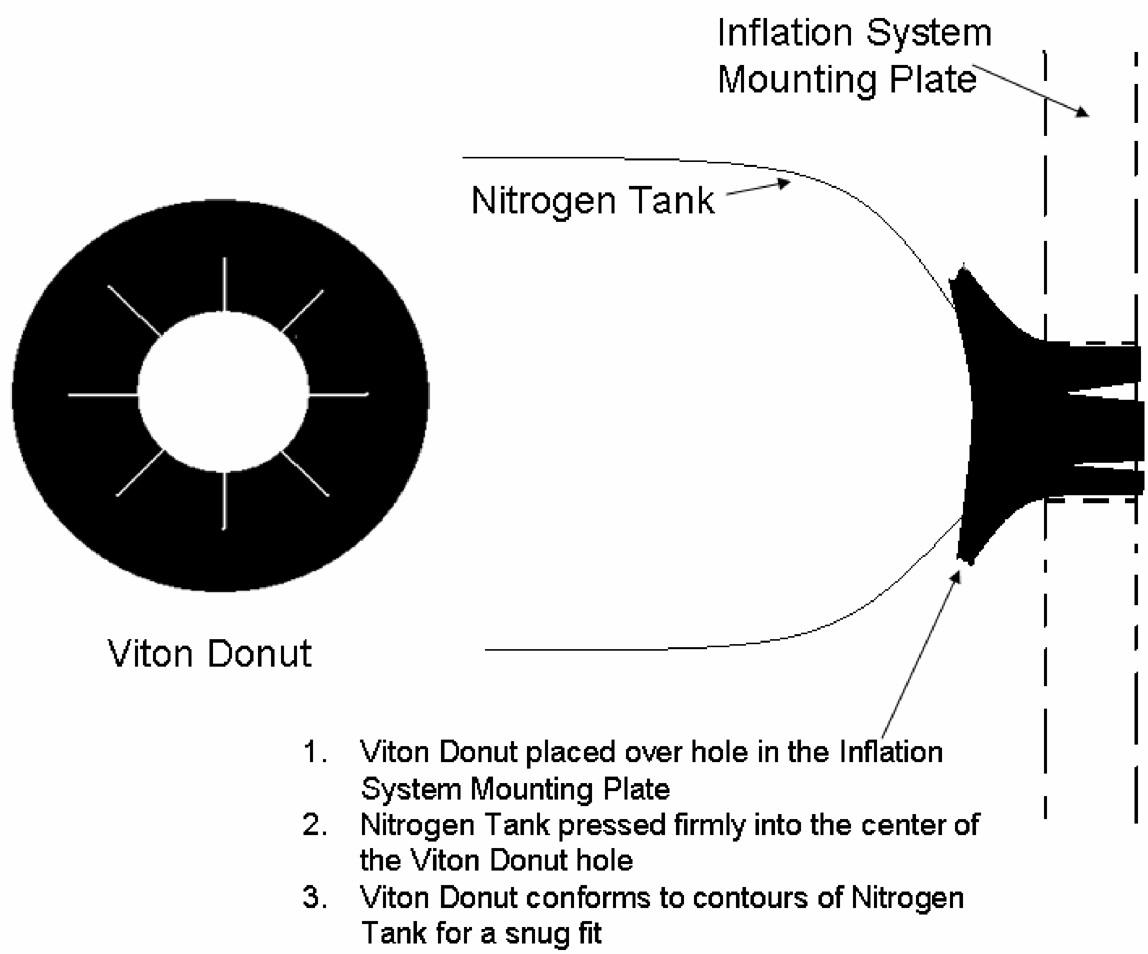


Figure 17: Viton Use for Mounting Pressure Vessels.

By cutting the Viton as shown in Figure 17, the pressure vessels were protected from movement in all directions. This was fortunate since the pressure vessels act as a base for all the other inflation system components. Figure 18 shows the inflation system components installed as part of the first wave of construction.

Figure 18: Wave 1 Construction.

4.2 Wave 2 Construction

Wave 2 Assembly was integrated with RP-6, RIGEX Electrical Component Assembly. During Wave 2, numerous holes needed to be drilled and tapped for electrical component attachment. Unfortunately, Wave 2 assembly was plagued with broken drill bits, broken taps, and misaligned holes. Additionally, structural analysis performed by

STP during Wave 2 construction yielded a negative margin on two of the fasteners securing the experimental top plate to two of the ribs. This analysis brought construction to a halt.

STP used a seasoned bolt analysis software program to identify two of RIGEX's fasteners as having negative margins, meaning that the potential existed for these two joints to fail structurally. More specifically, the concern was that the screws would shear the threads in the aluminum rib and pull out of the rib. This case was unacceptable for flight. Detailed documentation of the STP bolt analysis can be seen in Appendix E. Several methods of solving this problem were presented. For example, Figure 19 shows a proposed design change that incorporates a clearance hole with a washer and locknut to attach the experimental top plate to the top of the ribs.

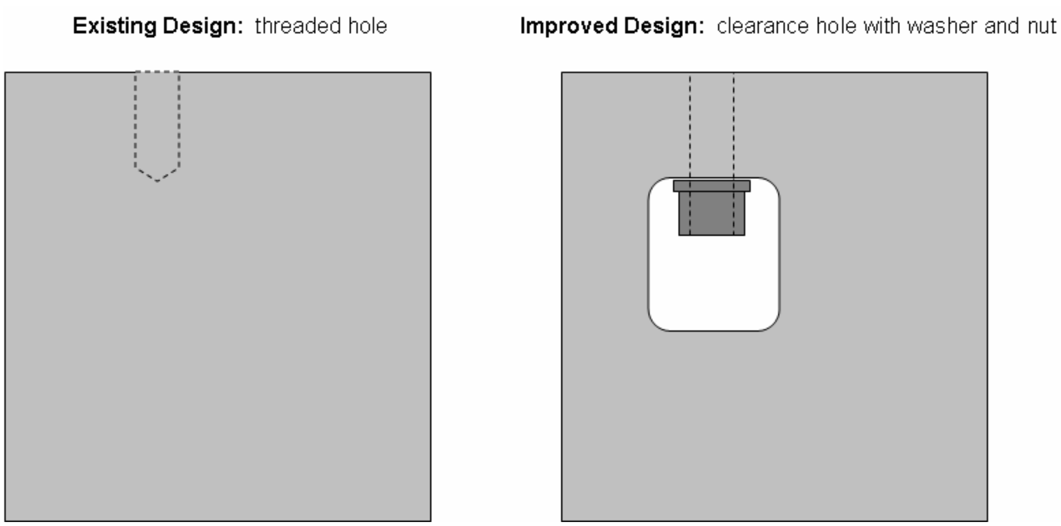


Figure 19: Optional Modification to Rib-to-Experimental Top Plate Fastening.

Time constraints, machining difficulties, and analysis delays forced the AFIT team to decide between four options presented by the engineers at STP. The following is a brief explanation of each option.

1. Drill and tap rib-to-experiment top plate holes deeper, if possible. Modify top plate for counter bores. Re-run analysis using longer fasteners.

2. Drill and tap rib-to-experiment top plate holes deeper with the addition of a Heli-coil insert, if possible. Re-run analysis using stronger screw

3. Add another hole for an additional screw near the negative margin screws. Adding a screw will help share the load and possibly bring margins lower than current design.

4. Keep design as is. Perform pull tests to obtain a higher allowable stress to use in the analysis. This would require permission from JSC Materials and Structures Working Group. AFIT would have to build at least 25 samples plus 4 or 5 tensile coupons from the parent material.

With much chagrin from the AFIT machine shop, the AFIT team decided to carry out option #1. Per STP's recommendations, a longer socket head cap screw and washer were used in place of the original countersunk screw.

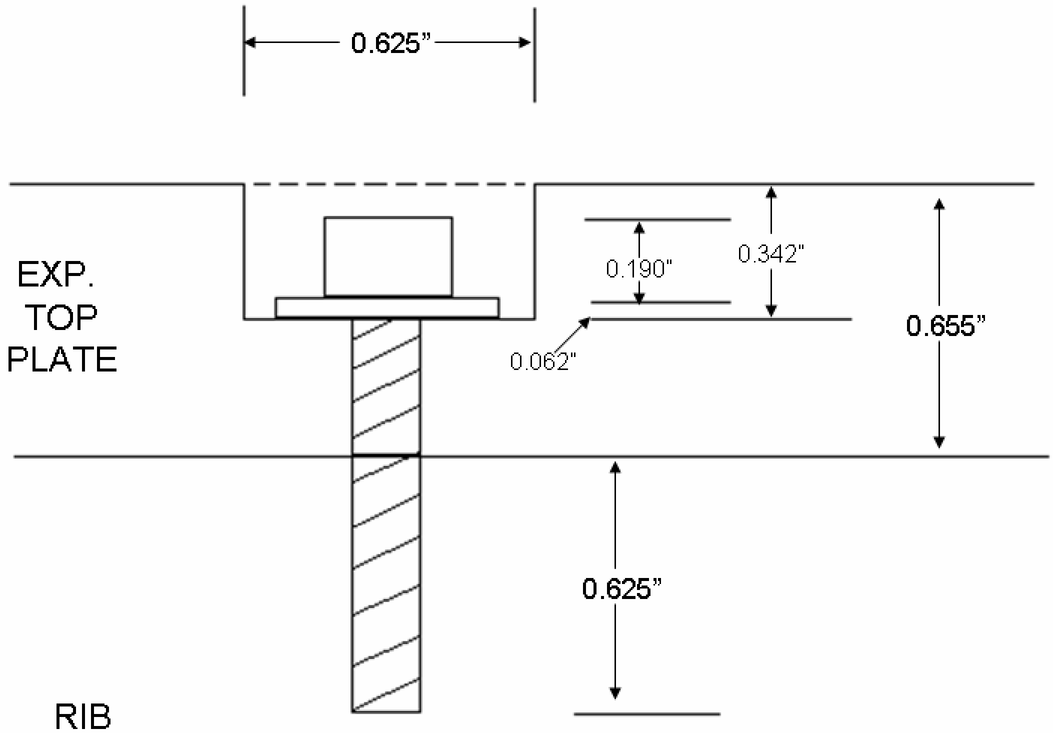


Figure 20: New Design for Experimental Top Plate Fasteners.

Figure 20 shows the new design implemented by the AFIT team. Special washers with a countersunk through hole were selected for this application. These washers are used under bolt heads for flight because the bolt’s specifications allow for a small fillet under the bolt head. It is important to avoid having the fillet resting on the edge of the washer’s inner diameter. Otherwise, it would create a stress concentration under the bolt head. The role of these washers, just like any washers, is to provide a harder material for the bolt head to bear against as it is torqued down and to spread the load in the joint. Without a washer, the socket head cap screws would have very little area interfacing with the aluminum plate, particularly if the clearance hole is large.

Before Wave 2 construction commenced, the RIGEX structure was delivered to the AFIT machine shop in order to fabricate the shroud. While in construction, a design oversight was discovered regarding shroud attachment. Button head cap screws were called for to fasten the shroud to the four ribs, Oven Mounting Plate, and the Experimental Top Plate. However, the ribs did not mount to the shroud in a perpendicular fashion. If installed, the head of the screw would be incorrectly placed under a bending load. To alleviate this issue, the AFIT team requested custom triangular washers be made to fill the void and allow the button head cap screws to be loaded correctly, as seen in Figure 21.

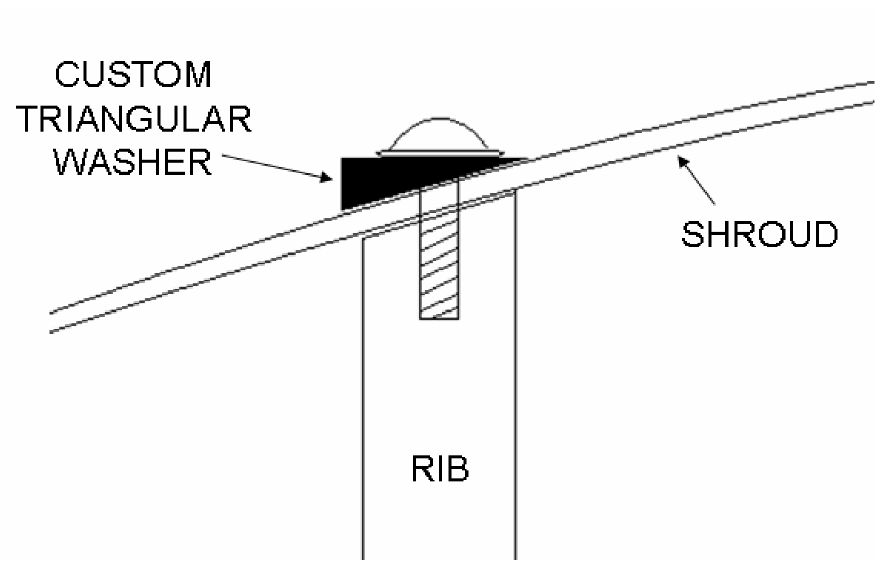
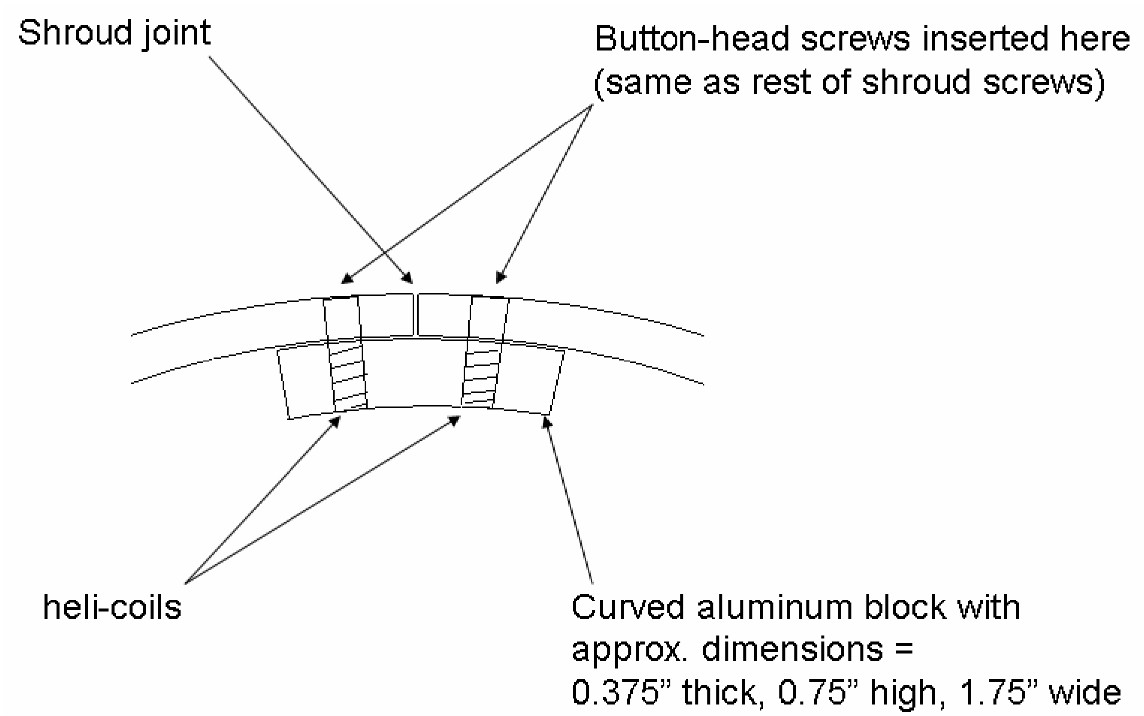


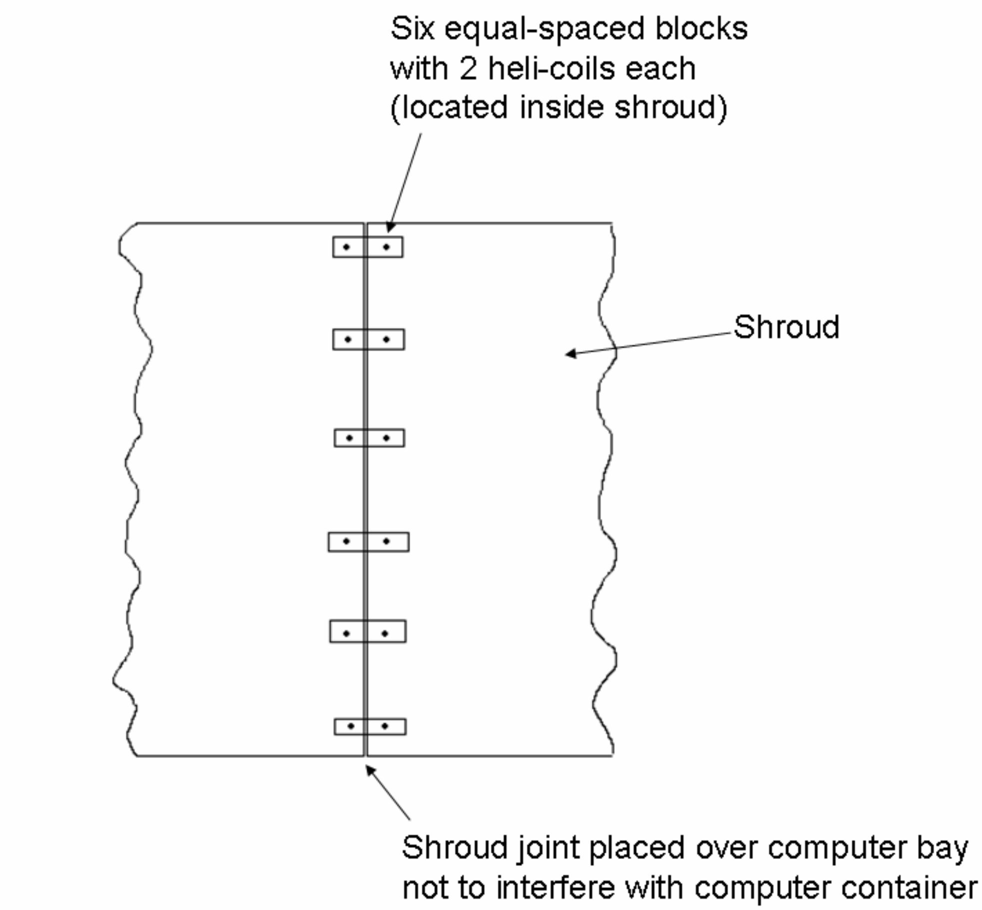
Figure 21: New Shroud Washers.

The shroud was originally designed with a one-inch overlap to secure the two edges. This overlap was to be placed at one of the ribs and secured using the shroud fasteners. When put to practice, this design did not work. The thick shroud seam forced the screw heads to protrude as far as the Delrin bumpers at the base of RIGEX. Consequently, a

new seam attachment design was generated and fabricated. The figures below illustrate the new design for securing the shroud's seam. It incorporates six aluminum blocks inside the shroud's inner diameter.



(a)



(b)

Figure 22: New Shroud Seam (a) Brackets and (b) Placement.

Wave 2 construction coincided with the attachment of electrical components and wiring. Both of these tasks were performed in accordance with RD-6. Figure 23 illustrates the complexity of RIGEX's wiring architecture. Multiple wire colors were helpful in keeping track of which wires came from which component. In Figure 23, all through holes that penetrate RIGEX's interior are taped closed. This was done in an effort to minimize contamination of the inner compartment created by the four ribs.

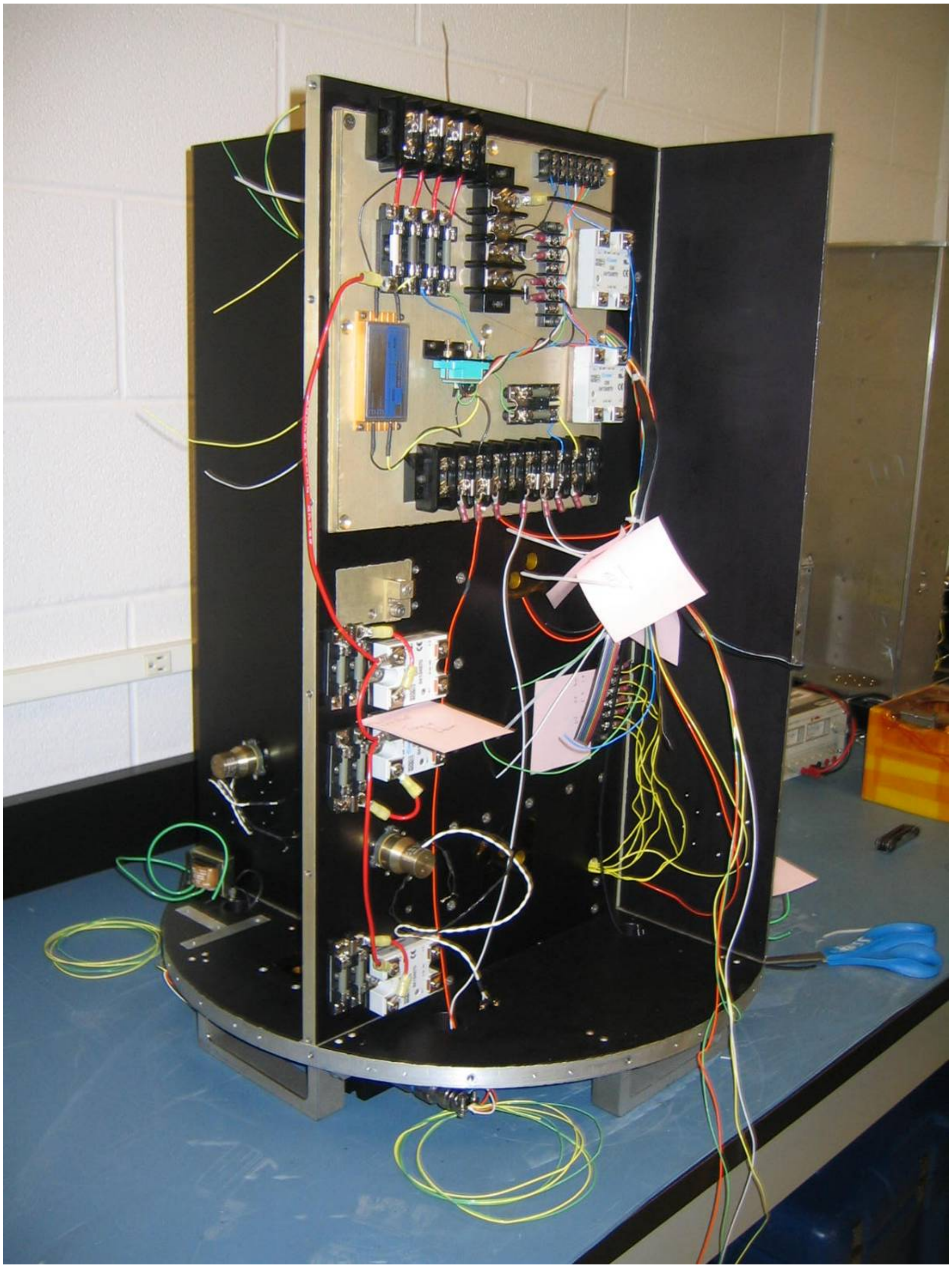


Figure 23: Wave 2 Construction.

The figure above illustrates the integration of the Wave 2 assembly with the electrical component wiring. As wires were added, more attention was needed to keep the wires in order.

The figure below shows the bottom side of RIGEX's Oven Mounting Plate. Bending the ¼" stainless steel tubing for a snug fit proved to be a difficult task. Nonetheless, all pressure system components were fitted as designed.

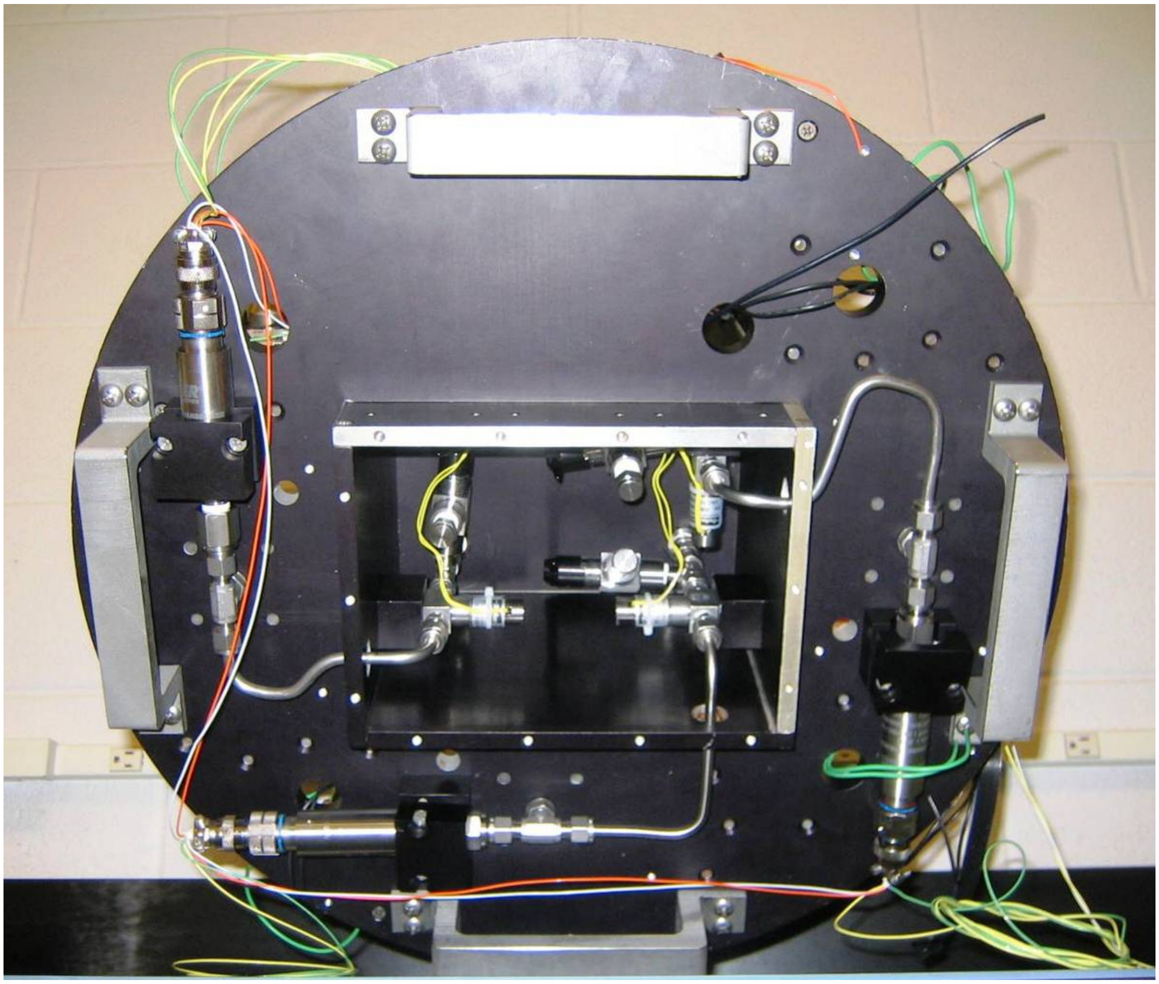


Figure 24: Completed Pressure System Assembly.

The oven assemblies used to heat the sub-Tg tubes were wired and wrapped with insulation. The insulation is used to help contain heat within the oven by re-radiating heat energy back towards the tubes. The oven assemblies were built with every effort to minimize the chance of the tube being snagged during inflation. For example, the oven

door hinges were mounted outside of the oven for clearance inside the oven, as illustrated in the figure below.

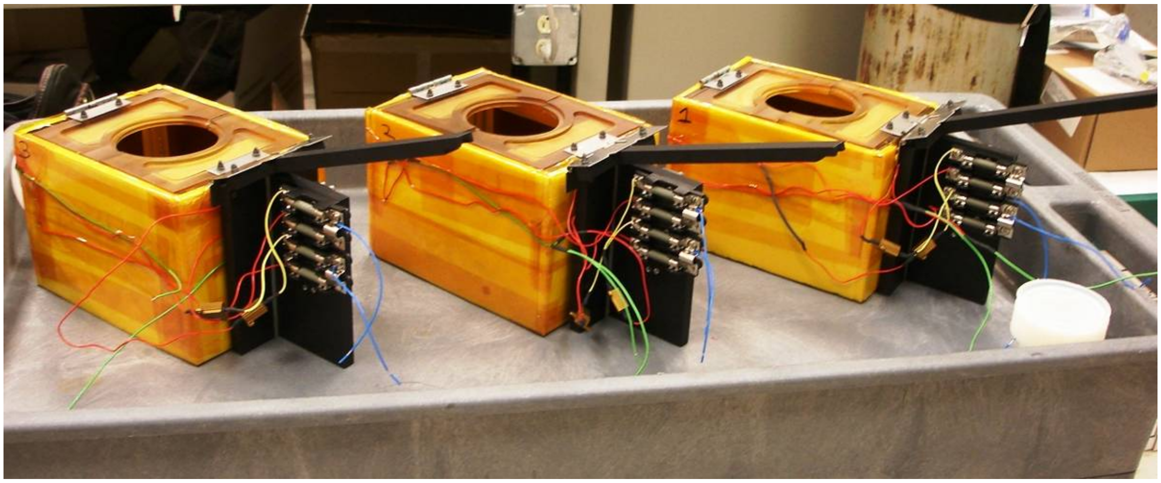


Figure 25: Completed Oven Assemblies.

4.3 Wave 3 Construction

The final wave of RIGEX's construction will take place once RIGEX is ready to be shipped to Johnson Space Center (JSC) for further space qualification testing. Wave 3 of the construction includes all elements on RIGEX held in place with locking Heli-coils and bolts. Appendix C, Wave 3 Assembly, describes the process for attaching the remainder of the components and applying torque to all of their respective fasteners. A fit check has been completed with all components to be installed during the last wave of construction. All components fit according to the designs.

Certain elements of the Wave 3 assembly are intended to be repeated multiple times. For example, when RIGEX is shipped to JSC and KSC, neither the shroud nor the CAPE mounting plate will be installed. These steps will be performed on-site due to

RIGEX's shipping configuration. In instances when an assembly step will be performed multiple times, the Wave 3 Assembly Procedure will also be used multiple times. Each iteration of a particular step will be documented in the Wave 3 Assembly Procedure.

4.4 Assembly Summary

The mechanical assembly of the RIGEX structure consists of three waves of subassemblies, Waves 1, 2, and 3. All assembly steps are documented in controlled documents, seen in Appendices A, B, and C. These controlled documents fulfill NASA's requirement to provide proper documentation for the construction of a space payload. In addition, they provide details on any modifications made during assembly that deviate from the original design. Once RIGEX is fully assembled and tested in an ambient environment, it will be ready for shipment to JSC for space qualification testing. This testing is discussed in detail in the next chapter of this thesis.

V. Space Qualification Testing of RIGEX

Over the past few months, AFIT's ability to test space payloads and qualify them for flight has improved dramatically. AFIT currently maintains a vibroacoustic test table and a thermal vacuum chamber for space payload testing. This chapter discusses the reasons and methods for qualification testing of the RIGEX payload.

5.1 Thermal Vacuum

The overall goal of NASA's strict and laborious ground testing requirements is to ensure that payloads achieve mission success in a safe manner. This lengthy list of requirements tests everything from sharp edges to electromagnetic interference. Requirements for flight differ greatly depending on the type of payload. The RIGEX program has a specific set of testing requirements since RIGEX will be installed inside CAPE and attached to the space shuttle's Get-Away-Special (GAS) beam.

According to the *CHUG*, all components need to demonstrate that they can function properly in the thermal extremes of the space environment (3). The space environment is dramatically different than the Earth's atmosphere. In space, there is no atmosphere. Consequently, heat transfer in space is only achieved through conduction and radiation. Convective heat transfer cannot take place due to the vacuum of space. Conduction heat transfer is achieved when thermal energy is transferred by molecular movement through a material or combination of mating materials. The rate of conduction can be described by the equation

$$Q = \kappa A(T_{hot} - T_{cold}) \quad (2)$$

where Q equals the heat transfer rate per second, κ equals the thermal conductivity coefficient of the material, A equals the surface area of conduction, and T is the absolute temperature. Radiation heat transfer occurs when a body emits electromagnetic waves that carry thermal energy to another object. Radiation heat transfer can be described by Stefan-Boltzmann equation

$$Q = e\sigma A(T - T_{cold})^4 \quad (3)$$

where Q equals the heat transfer rate per second, e is the emissivity of the object, σ is the Stefan-Boltzmann constant ($5.56 * 10^{-8}$ J/(s-m^2-K^4), A is the surface area of the object, and T is the absolute temperature. Heat transfer always occurs in the same direction – hot to cold.

Advanced ground testing techniques and equipment attempt to mimic all of the environmental conditions of space, except for zero gravity. A thermal vacuum (TVAC) chamber can be used to simulate the extreme temperatures and complete vacuum of the space environment. A thermal vacuum chamber uses flourinert fluid in a radiator to cool or heat a conductive platen. Figure 26 shows the chamber’s platen. The platen thermally controls whatever test object is placed on top. Vacuum pumps are used to purge the ambient air from the pressure vessel.

Figure 26: AFIT TVAC Platen Pulled Open to Access Test Panel.

AFIT acquired a custom TVAC chamber from PHPK Technologies out of Columbus, OH in 2006 to conduct testing on RIGEX and future space payloads. The PHPK TVAC chamber allows for a 30”x30”x48” object to be tested in a thermally controlled vacuum. AFIT’s chamber uses liquid nitrogen for cooling, and an electric resistive heater for heating. To achieve a vacuum on the scale of 10^{-7} torr (1 ATM = 760 torr), the PHPK TVAC chamber uses two vacuum pumps. A roughing pump decreases the pressure to approximately 10^{-2} torr, at which time a turbo pump is turned on in addition to the roughing pump to bring the pressure all the way down to 10^{-7} torr. A typical value for space qualification testing is a vacuum of less than 10^{-2} torr.

Figure 27: AFIT TVAC Chamber Front Door.

The AFIT TVAC chamber, pictured above, is controlled using a touch-screen computer display, shown in Figure 28. All functions are automated except for returning the chamber to ambient pressure. To return the chamber to ambient pressure, a Swagelok T-valve needs to be turned open by hand. A complete set of user instructions was provided by the manufacturer, as well as hands-on training on operating the chamber's control software.

Figure 28: AFIT TVAC Chamber Rear Control Panel.

The importance of testing RIGEX in a thermally controlled environment is paramount to mission success. Many components have different *operating* and *survivable* temperatures, and it is essential that these temperatures be determined through testing. The operating temperatures of a piece of hardware are the range of temperatures for which the hardware is rated to function properly. The survivable temperatures of a piece of hardware are the range of temperatures at which the hardware can be stored. An item only has to survive at the survivability temperature, not function. For example, the accelerometers used on RIGEX are manufactured to operate correctly at -40°C to 85°C. However, the survivable temperatures of the accelerometers are -55°C to 150°C. A

complete list of the operational and survivability temperatures for all RIGEX hardware can be viewed in Appendix G.

Table 2: Abbreviated Operational and Survivability Table.

	Operating Limits				Storage Limits*			
	Temp (^{o}C)		Humidity %		Temp (^{o}C)		Humidity %	
Subsystem	Low	High	Low	High	Low	High	High	Low
Command and Control								
Thermocouple (data acquisition)	-25	85	N/A	N/A	-25	85	N/A	N/A
Power Distribution								
Solid State Relays: output Solid State Relays: input	-20	80	N/A	N/A	-40	100	N/A	N/A
Imaging System								
Cameras	-20	100	N/A	N/A	-20	100	N/A	N/A

Table 2 highlights the components on RIGEX whose manufacturer's specifications do not meet the thermal operational requirements set forth by STP. As a result, the components found in Table 2 require TVAC testing to validate their functionality at temperature extremes. In most cases, the components are not rated to such extreme temperatures as those found in space due to the fact that they were never tested by their manufacturer to perform at these high and low temperatures. Successful ground testing in a TVAC chamber is a legitimate way to thermally certify components for space flight. Figure 29 shows a picture of the initial set-up of AFIT's TVAC chamber. The chamber was delivered by the manufacturer with no thermocouples and no power supply lines.

Figure 29: AFIT TVAC Power Lines Installation.

Upon successful installation and set-up of the AFIT TVAC chamber, RIGEX components in need of thermal qualification were tested. In order to facilitate this testing, the TVAC chamber needed to be equipped with at least eight thermocouples for data acquisition. K-type thermocouples were used in a variety of locations for testing.

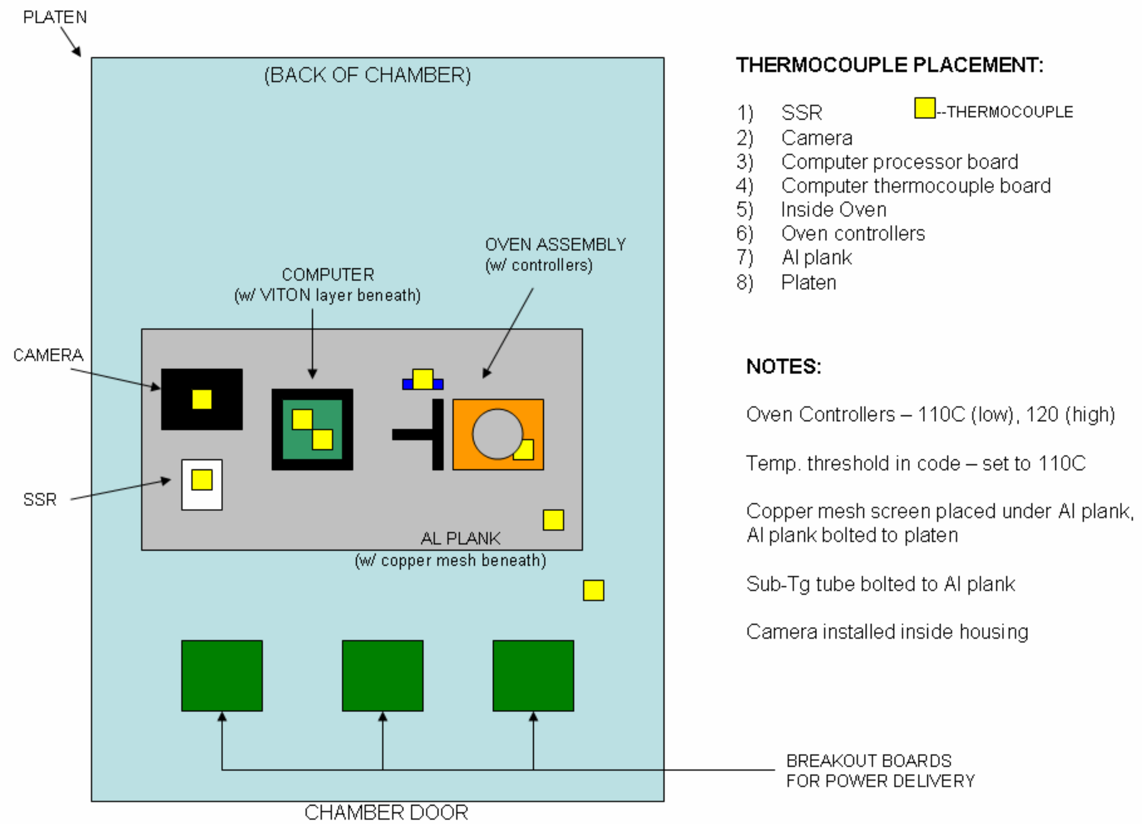


Figure 30: TVAC Test #1- Experimental Set-Up Schematic.

Figure 30 illustrates the layout of the first series of components tested in the TVAC chamber as well as the placement of the thermocouples. The component test was set up in hopes of achieving the closest flight configuration possible. In other words, the goal was to test RIGEX like it flies. All items tested in the component test functioned properly at both hot and cold temperature extremes. Further TVAC testing will be completed using the entire RIGEX structure.

5.2 Vibration Testing

Launching RIGEX into space and expecting it to perform as designed is a lofty goal. This is especially true considering the fact that RIGEX will sit idle for months during shuttle launch preparation, only to be followed by a violent launch into space. RIGEX's structural integrity cannot deteriorate over time. NASA document NSTS 37329, Rev. B dictates that payloads must undergo vibration testing in order to ensure that a payload is fit for space flight (16). NSTS 37329 states that "a series of structural analyses will be performed to verify the structural compatibility of the Cargo Element (CE) with the Orbiter and with other CEs in the cargo bay manifest" (16). This document provides a scope for testing space flight payloads with regard to random vibration analysis, modal frequency analysis, and displacement. Vibration testing of flight payloads is accomplished through a series of different tests. Typically, structures undergo a structural stiffness verification test and a random vibration test, followed by a second structural stiffness verification test. Data from these tests is collected through the use of accelerometers installed on the structure during testing. For the RIGEX/CAPE structure, both tri-axial and single axis accelerometers will be used in a variety of locations.

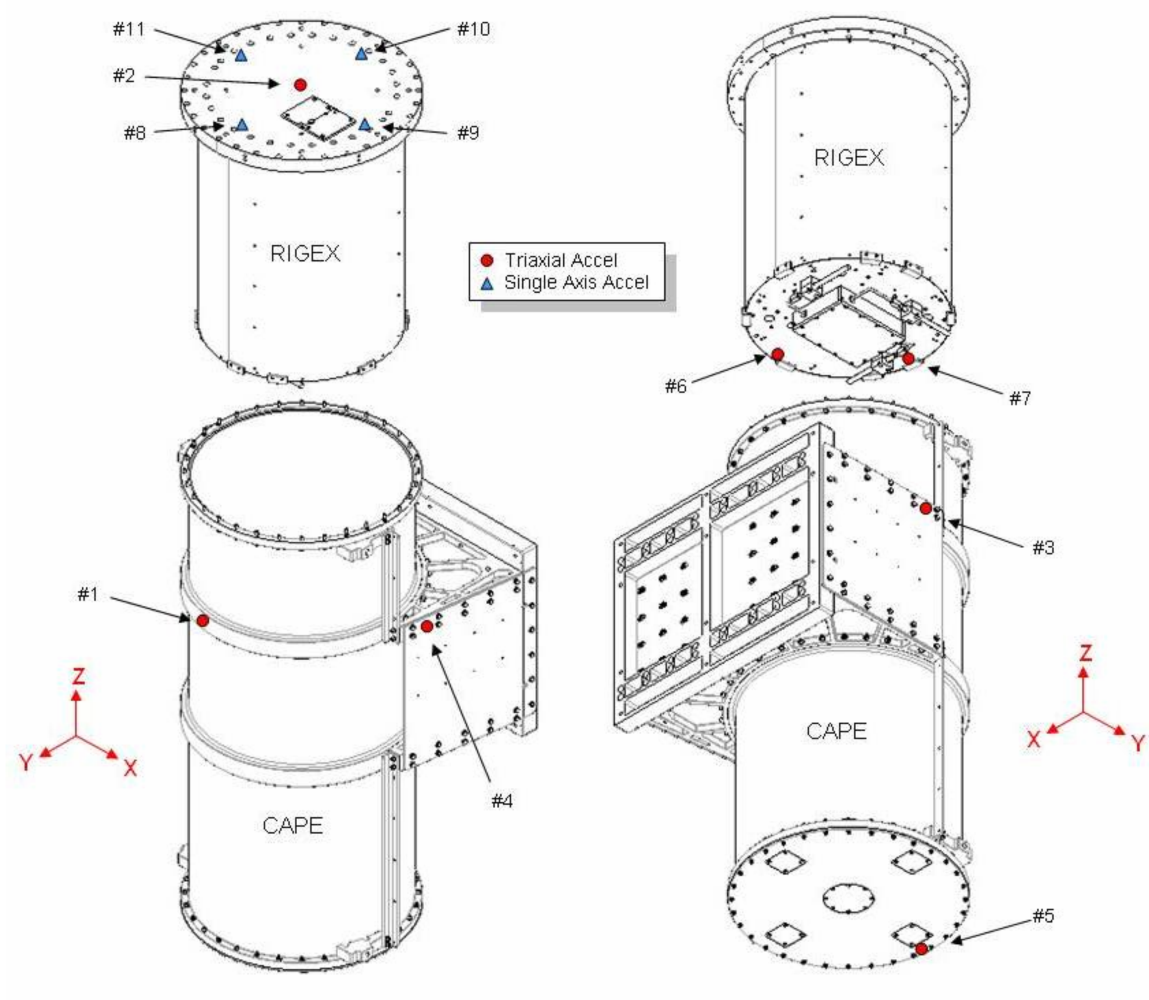


Figure 31: RIGEX/CAPE Accelerometer Locations (19).

Figure 31 shows the approximate placement of the accelerometers that will be used during RIGEX/CAPE vibration testing. The placement of the accelerometers was the decision of the engineers at STP and coordinated with AFIT. The most critical position is thought to be the #6 and #7 accelerometers because they are placed on the furthest cantilevered position.

A structural stiffness verification test, also called a sine sweep test, consists of a series of acceleration/force sweeps through different frequencies. In doing so, the natural

frequency of the structure being tested can be determined. The fundamental resonance, or natural mode, of a structure is the first significant measured frequency that matches the input frequency. During testing, the transfer function of the system is measured to determine the structural frequencies. This is based on using Newton's 2nd Law, relating the forces acting at a particular point on a structure to its acceleration.

$$F = ma \tag{3}$$

The forces F include both internal forces acting at the point where the acceleration is measured as well as any externally applied forces. Taking the Laplace Transform of Equation (3), the transfer function can be expressed as

$$\frac{X(s)}{F(s)} = \frac{s^2}{ms^2 + bs + k} \tag{4}$$

where m represents the mass, b the system damping, and k the structural stiffness. The resonance of the structure are input frequencies ($F(s)$, $s=j\omega$) where the denominator in Equation (4) approaches zero. Assuming a constant mass, the natural frequency corresponds directly with the value of k in Equation (4). For the RIGEX/CAPE structure, the design goal is to achieve a natural frequency greater than 35 Hz (19).

First, a sine sweep test is performed three times, once for each axis in three-dimensional space. The sine sweep tests results creates a set of frequency response data, Equation (4), for a particular structure. This data can be thought of as the payload's fingerprint. After the initial sine sweep test in each axial direction, a random vibration test is performed. The random vibration test is different from a sine sweep test in that a

random vibration test varies excitation frequency over a prescribed range of input frequencies based on the particular launch vehicle. Since the shuttle experiences random vibration during launch, this test is a good simulation of actual flight. For the RIGEX/CAPE structure, the maximum expected flight level (MEFL) to be used for random vibration testing is 6.8 Grms (19). This level was developed in accordance with data provided by NASA document NSTS 21000-IDD-SML (19). The RIGEX/CAPE structure will undergo random vibration testing in three orientations, one for each axis in three-dimensional space.

Table 3: Random Vibe Test Levels (19).

X-Axis	
FREQ (Hz)	**ASD (G^2/Hz)**
20.00	**0.010000**
80.00	**0.040000**
500.00	**0.040000**
2000.00	**0.010000**
Y-Axis	
FREQ (Hz)	**ASD (G^2/Hz)**
20.00	**0.010000**
45.00	**0.060000**
600.00	**0.060000**
2000.00	**0.010000**
Z-Axis	
FREQ (Hz)	**ASD (G^2/Hz)**
20.00	**0.010000**
70.00	**0.050000**
600.00	**0.050000**
2000.00	**0.010000**

Table 3 identifies the auto spectral density (ASD), which is the specific level of random vibration that the RIGEX/CAPE structure will experience in each axial direction. It is critical to note the importance of orientation for the random vibration tests. RIGEX is

only designed to fly in one particular orientation in the shuttle. The values used for testing reflect this particular orientation accordingly.

Following the random vibration test, the RIGEX/CAPE structure will undergo a second sine sweep test. The data collected during this second sine sweep test will be used to create a second fingerprint for the structure. The fingerprints of the first and second sine sweep tests are compared to determine if the structure survived the random vibration levels. If the first and second fingerprints match, the RIGEX/CAPE passes vibration testing. In most cases, a payload passes if the first and second test results are within a few percent of one another. A case by case analysis is used by NASA to determine how well a payload performed during vibration testing.

Table 4: Ultimate Mechanical Factors of Safety (15).

ULTIMATE MECHANICAL FACTORS OF SAFETY

Material	Tested	Not Tested
Standard Metallic (e.g., aluminum, steel, etc.)	1.4	Note 1
Glass	3.0	5.0
Non-metallic for non-discontinuity areas	1.4 Note 2	Note 1
Non-metallic for discontinuity areas	2.0	Note 1

Notes: 1. The SSP Structures Working Group (SWG) will determine the appropriate value based on the proposed usage.

2. The 1.4 value is applicable when a prototype verification approach is being used. This value becomes 1.5 when a protoflight verification approach is used.

Table 4 identifies the factor of safety used by NASA to help determine a vibration testing profile. RIGEX is a protoflight model built out of aluminum, so its ultimate mechanical factor of safety is 1.5. Since RIGEX will be flown inside the Canister for All Payload

Ejections (CAPE) assembly, RIGEX will be installed inside of CAPE for testing. The purpose of testing RIGEX inside CAPE is to simulate the forces that will be felt in the actual flight configuration. RIGEX will not be exposed to a stand-alone test due to the risk of over-testing and potentially damaging flight hardware. Typically, a workmanship vibe test is completed on flight hardware. This workmanship test is a stand-alone vibration test of lesser magnitude than the launch vibration test. The goal of a workmanship test is to ensure that a payload is structurally sound before being tested at Johnson Space Center (JSC). For the builders, a workmanship test provides assurance that no mistakes were made during assembly. For the engineers at JSC, a workmanship test provides assurance that a payload is ready to be tested and justifies the use of expensive facilities and resources. The decision to do without a workmanship vibe test on RIGEX was made because it was impossible to predict the actual loads RIGEX will experience during flight. The engineers at STP believed that the loads may be slightly damped since RIGEX will be inside CAPE. Therefore, STP engineers were skeptical of completing a workmanship vibration test on a flight prototype for fear that if the acceleration values were wrong, the structure might fail. Because RIGEX is only a prototype, the RIGEX team would have no back-up plan, and thus, mission failure.

Vibration testing for the RIGEX/CAPE structure will take place at the Vibroacoustic Test Facility, Building 49, at Johnson Space Center (JSC) in Houston, TX. The RIGEX Vibration Test Plan was developed by Taylor, the RIGEX Payload Integration Engineer (19). This document, shown in Appendix D, provides the specifics of how vibration testing will be carried out while RIGEX is in Houston, TX. Every effort

was made to test RIGEX/CAPE like it will fly. However, RIGEX will not be configured exactly the same for testing and flight. During testing, RIGEX will be fitted with test sub-Tg tubes and Ground Support Equipment (GSE) cables. Both of these items will be swapped out and replaced with flight-certified components prior to launch.

In order to facilitate a successful test, numerous details needed to be worked out between AFIT and STP. Through conversation via teleconference, details of how RIGEX would be received at JSC, processed at JSC, tested at JSC, and returned home to AFIT were determined. A ground flow schematic was developed as a plan for RIGEX's movement while at JSC.

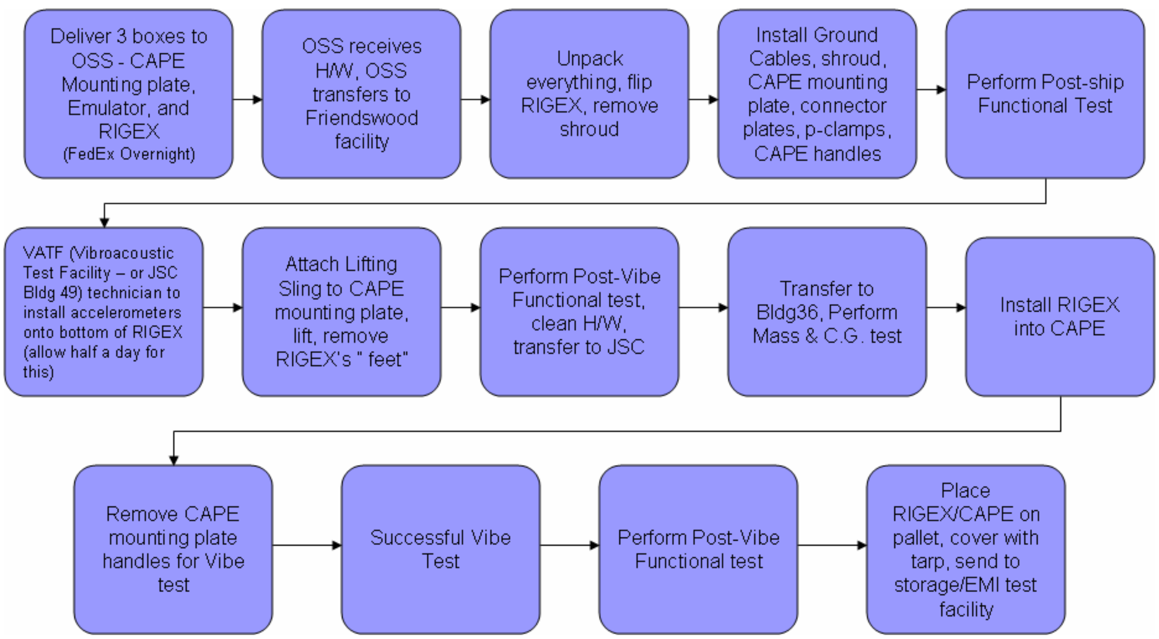


Figure 32: RIGEX Ground Flow Schematic for JSC Vibration Test.

Figure 32 shows a top-level flow diagram used to guide RIGEX through the various phases of the vibration test. Due to the relatively high weight of RIGEX, almost 200 pounds, special care needs to be taken so that RIGEX is only lifted by mechanical lifting

devices, such as a fork lift or crane. A specific set of directions illustrating how RIGEX will be handled while at JSC is found in the RIGEX Handling Procedure, RP-8.

5.3 Testing Summary

It is the hope of the entire RIGEX team that RIGEX will successfully pass all testing required for space flight qualification. In the event of a test failure, the RIGEX team will analyze the failure mechanism and either test again or modify the design. Passing all of the elements of space qualification testing would propel the RIGEX program towards a bright future and closer to space flight. The next chapter of this thesis discusses the future of the RIGEX program.

VI. Discussion and Future Work

The RIGEX program is AFIT's first effort at a complete design/build/qualify and space flight test of a shuttle experiment. Although the development of RIGEX has taken far longer than expected, designing and testing RIGEX has given AFIT many good examples from which to learn. As RIGEX nears completion, it is important to look ahead towards the future of the RIGEX program, both immediate and long-term. This chapter discusses some of the goals that the RIGEX team expects to meet, as well as some of the lessons learned along the path towards launch.

6.1 Future RIGEX Work

The proposed launch date for the RIGEX program is February 2008. In order to meet the future deadlines set forth by NASA, RIGEX must pass numerous tests and fulfill a variety of requirements. The largest and most critical hurdles that face the RIGEX project include successfully passing vibration testing and electromagnetic interference (EMI) testing at JSC. Smaller tests such as a sharp edge inspection, a mass and CG test, and Interface Verification Test (IVT) also need to be successful. The purpose of the Sharp Edge Inspection is to determine whether or not any surfaces exposed to the shuttle's payload bay have the potential to tear an astronaut's space suit. Since RIGEX's CAPE Mounting Plate will be exposed to the payload bay, its edges must be shown to be smooth. A Mass and CG Test is designed to determine the total mass and the centroid of a payload. This data is used to compare with a simulated computer model

to ensure that all structural analyses performed are correct. The purpose of the IVT test is to make certain RIGEX is compatible with the Orbiter's electrical power buses. With the help of the engineers at STP, the AFIT team has prepared RIGEX to be successful in each event leading up to launch.

When RIGEX is cleared for flight, it will be expected to survive the journey into space and perform three identical experiments in the space environment. Many factors contribute to the mission success of the experiment while in space. It is the hope of the AFIT team that through extensive analysis and thorough testing, all systems will function properly and RIGEX will land with quality data. Post-processing of the data must be performed in order to make any conclusions about the performance of the sub-Tg tubes in space. Additionally, further ground testing must take place in order to simulate the as-flown configuration of the tubes. For example, the flight ribbon cable attached to each accelerometer on RIGEX is stiffer than the cable used during ground testing. Since the flight ribbon cable is less-pliable than the cable used during ground testing, the results of tube deployment and excitation may differ.

If RIGEX is successful in gathering experimental data in the space environment, future rigidizable inflatable experiments would be in order. These future experiments could deploy longer sections of tubing, or even deploy an actual structure such as a truss. If RIGEX is unsuccessful in gathering quality data in space, a similar RIGEX could be redesigned from the ground up to be lighter and more robust. This would be far less of a task than the development of the first RIGEX due to the wealth of knowledge accumulated over the past several years.

6.2 Lessons Learned

The AFIT space payload program is still in its infancy. However, in the short period of time that it has taken to assemble RIGEX, a great deal of information has been acquired. Unfortunately, this body of knowledge is rooted in graduating students. The RIGEX program would benefit greatly if there was a constant source of knowledge that could contribute to the experiment at each stage of the project. This knowledge base must include more than just faculty members and technicians. It must include full time students that follow the project from conception to delivery at KSC. This level of commitment may seem daunting, but it would significantly reduce the length of time for research and ground testing.

As a result of the RIGEX project, AFIT is more equipped, better connected, and smarter about how to approach the needs of a NASA deliverable. For example, during the construction of RIGEX, the AFIT tool supply increased dramatically due to the particular needs of odd fasteners on RIGEX. AFIT can now test projects in a large scale thermally controlled vacuum environment. The AFIT machine shop has proven that they are a proficient and flexible asset to space projects. RIGEX's needs have opened many doors to quality vendors and trustworthy contractors whom AFIT would have never known otherwise.

Attempting to understand the intricacies of the NASA document tree is overwhelming. Now that AFIT has been through one iteration of the payload documentation process, future projects will have a much easier time keeping records and

preparing paperwork. This is particularly important because preparing documentation for NASA is never a popular task. In addition to the documentation and analysis associated with a space project, extensive testing is required. Fortunately, AFIT is prepared to test future projects with state-of-the-art equipment.

A vital part of achieving mission success on any experimental space project is to establish a prototype capable of setting the standard for real flight hardware. No real prototype of RIGEX was built to help solve fabrication and functionality issues. Instead, RIGEX is a protoflight model. It would be advantageous to construct a flight-like prototype model. Only after successful testing of the prototype model should the flight-ready model be made. Improving AFIT's software capabilities is an important step in attaining a fully qualified prototype model. If AFIT's software was on par with NASA's software, particularly finite element analysis capability, computer analysis discrepancies would be less of a burden to both AFIT and NASA.

6.3 Discussion Summary

AFIT has benefited from the experience gained throughout the course of the RIGEX project. Although the project still faces many challenges in the future, it is important to note that the RIGEX team has overcome numerous setbacks and obstacles. RIGEX has become a stable structure ready for official space qualification testing and launch. AFIT has become a proficient facility capable of producing and testing future space payloads.

Appendix A: Wave 1 Assembly (RP-1)

The following appendix contains the first of three assembly procedures used in the construction of the RIGEX protoflight model. This assembly procedure describes in detail the first subassembly of RIGEX.

Air Force Institute of Technology
Wright Patterson Air Force Base

RIGEX
MECHANICAL ASSEMBLY PROCEDURE (RP-1)

Prepared by:

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Issue IR   Doc Serial No. RP-1   Date 01-FEB-07

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CHANGE LOG				
Rev. Ltr. Change	Justification and Description of Change	Affected Pages	Release Date	Change Approval (*Initial & Date*)
IR	Initial Release	All	01-FEB-07	N/A
A	NPT fittings torque	5,7,12	01-APR-07	BDO 1Apr07

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Seq #	Instructions	Date	Tech	Insp
1.0 1.1 **2.0** 2.1	**Scope** This document provides step-by-step procedures for assembling the first sub-assembly of RIGEX. Assign Serial Number: _ RIGEX-1_____________ **Materials and Components** Obtain parts and materials from Certified Stores. Item numbers (#) herein are referenced in Table 1 at the end of this document.			
2.2	Record each lot number or serial number in Table 1 at the end of these procedures.			
2.3	Record each part number in Table 1 at the end of these procedures.			

Seq #	Instructions	Date	Tech	Insp
2.4	Record Tool Information Tool No. ____________________ Last Calibration Date ________ Next Calibration Date ________ Tool No. ____________________ Last Calibration Date ________ Next Calibration Date ________ Torque values in this procedure will be as follows: Running torque – torque experienced by torque wrench before major resistance is met Applied torque – difference between Running and Total Torque Total Torque – maximum torque experienced by torque wrench (i.e. Total = Running + Applied)			

RP-1

Seq #	Instructions	Date	Tech	Insp
3.0	**Inflation System Construction** NOTES: Before installing any bolts, apply alodine touch-up with swab stick to all threaded and unthreaded holes. Before applying torques, install all specified fasteners finger tight to ensure proper alignment. Use Teflon Tape (41) on all NPT fittings. For all compression fittings, tighten 1 and ¼ turn past finger-tight. The pictures at the end of this document may be used to help clarify these assembly procedures. Each picture is labeled as a sequence number, and these sequence numbers correspond to a particular step in the assembly procedure.			
3.1	Attach Small Rib without Pin Puller (6) to Large Computer Rib (3) using 12 NAS1189E3P12B (36); Running torque should be 2-18 in lbs; Applied torque should be 66 ±7 inlbs 1. Running____+ Applied: ____ = Total____ inlbs 12. Running____+ Applied: ____ = Total____ inlbs 2. Running____+ Applied: ____ = Total____ inlbs 11. Running____+ Applied: ____ = Total____ inlbs 3. Running____+ Applied: ____ = Total____ inlbs 10. Running____+ Applied: ____ = Total____ inlbs 4. Running____+ Applied: ____ = Total____ inlbs 9. Running____+ Applied: ____ = Total____ inlbs 5. Running____+ Applied: ____ = Total____ inlbs 8. Running____+ Applied: ____ = Total____ inlbs 6. Running____+ Applied: ____ = Total____ inlbs 7. Running____+ Applied: ____ = Total____ inlbs			

Seq #	Instructions	Date	Tech	Insp
3.2	Attach Bottom Inflation Mounting Plate (10) to Small Rib without Pin Puller (6) using 3 NAS1189E3P12B (36); Running torque should be 2-18 in lbs; Applied torque should be 66 ±7 inlbs 13. Running____+ Applied: ____ = Total____ inlbs 15. Running____+ Applied: ____ = Total____ inlbs 14. Running____+ Applied: ____ = Total____ inlbs			
3.3	Attach Bottom Inflation Mounting Plate (10) to Large Computer Rib (3) using 4 NAS1189E3P12B (36); Running torque should be 2-18 in lbs; Applied torque should be 66 ±7 inlbs 16. Running____+ Applied: ____ = Total____ inlbs 19. Running____+ Applied: ____ = Total____ inlbs 17. Running____+ Applied: ____ = Total____ inlbs 18. Running____+ Applied: ____ = Total____ inlbs			
3.4	Place each of the three Nitrogen Gas Tanks (25) in a hole on the Bottom Inflation Mounting Plate (10) and place Top Inflation Mounting Plate (9) on top of the Nitrogen Gas Tanks (25) to keep them from falling. Place Viton (35) between the ends of each gas tank and the inflation mounting plates. Use just enough Viton (35) so that there is no metal-on-metal contact.			
3.5	Attach Top Inflation Mounting Plate (9) to Small Rib without Pin Puller (6) using 3 NAS1189E3P12B (36); Running torque should be 2-18 in lbs; Applied torque should be 66 ±7 inlbs 20. Running____+ Applied: ____ = Total____ inlbs 22. Running____+ Applied: ____ = Total____ inlbs 21. Running____+ Applied: ____ = Total____ inlbs			

Seq #	Instructions	Date	Tech	Insp
3.6	Attach Top Inflation Mounting Plate (9) to Large Computer Rib (3) using 4 NAS1189E3P12B (36); Running torque should be 2-18 in lbs; Applied torque should be 66 ±7 inlbs 23. Running____+ Applied: ____ = Total____ inlbs 26. Running____+ Applied: ____ = Total____ inlbs 24. Running____+ Applied: ____ = Total____ inlbs 25. Running____+ Applied: ____ = Total____ inlbs			
3.7	Attach 1 Pressure Transducer (21) to the top of each Nitrogen Gas Tank (25). Attach adapter fitting to bottom of each tank. Tighten both until wrench tight, total torque should be greater than 100 inlbs. XDCR 1: Total____ inlbs XDCR 2: Total____ inlbs XDCR 3: Total____ inlbs Fitting 1: Total____ inlbs Fitting 2: Total____ inlbs Fitting 3: Total____ inlbs			
3.8	Attach Swagelok Fill Valve (27) and Pipe Tee (34) to the bottom of each Nitrogen Gas Tank (25). Tighten until wrench tight, total torque should be greater than 100 inlbs. Valve 1: Total____ inlbs Valve 2: Total____ inlbs Valve 3: Total____ inlbs			

Seq #	Instructions	Date	Tech	Insp
3.9	Attach Small Rib with Pin Puller (5) to Large Computer Rib (3) using 12 NAS1189E3P12B (36); Running torque should be 2-18 in lbs; Applied torque should be 66 ±7 inlbs			
	27. Running____+ Applied: ____ = Total____ inlbs			
	38. Running____+ Applied: ____ = Total____ inlbs			
	28. Running____+ Applied: ____ = Total____ inlbs			
	37. Running____+ Applied: ____ = Total____ inlbs			
	29. Running____+ Applied: ____ = Total____ inlbs			
	36. Running____+ Applied: ____ = Total____ inlbs			
	30. Running____+ Applied: ____ = Total____ inlbs			
	35. Running____+ Applied: ____ = Total____ inlbs			
	31. Running____+ Applied: ____ = Total____ inlbs			
	34. Running____+ Applied: ____ = Total____ inlbs			
	32. Running____+ Applied: ____ = Total____ inlbs			
	33. Running____+ Applied: ____ = Total____ inlbs			
3.10	Attach Bottom Inflation Mounting Plate (10) to Small Rib with Pin Puller (5) using 3 NAS1189E3P12B (36); Running torque should be 2-18 in lbs; Applied torque should be 66 ±7 inlbs			
	42. Running____+ Applied: ____ = Total____ inlbs			
	44. Running____+ Applied: ____ = Total____ inlbs			
	43. Running____+ Applied: ____ = Total____ inlbs			
3.11	Attach Top Inflation Mounting Plate (9) to Small Rib with Pin Puller (5) using 3 NAS1189E3P12B (36); Running torque should be 2-18 in lbs; Applied torque should be 66 ±7 inlbs			
	39. Running____+ Applied: ____ = Total____ inlbs			
	41 Running____+ Applied: ____ = Total____ inlbs			
	40. Running____+ Applied: ____ = Total____ inlbs			

Seq #	Instructions	Date	Tech	Insp
3.12	Use Tubing (26) and attach the Solenoid Valve (30) to the bottom of each Swagelok Fill Valve (27) and Pipe Tees (34). Fitting 1: Total____ inlbs Fitting 2: Total____ inlbs Fitting 3: Total____ inlbs Fitting 4: Total____ inlbs Fitting 5: Total____ inlbs Fitting 6: Total____ inlbs Solenoid Valve (30) will be attached to adjacent rib via Solenoid Mounting Block (29). Each Solenoid Mounting Block (29) will use NAS1189E3P12B (36) to attach to adjacent rib (Running torque should be 2-18 inlbs; Applied torque should be 66 ±7 inlbs) Mounting Block 1: 45. Running____+ Applied: ____ = Total____ inlbs 46. Running____+ Applied: ____ = Total____ inlbs Mounting Block 2: 47. Running____+ Applied: ____ = Total____ inlbs 48. Running____+ Applied: ____ = Total____ inlbs Mounting Block 3: 49. Running____+ Applied: ____ = Total____ inlbs 50. Running____+ Applied: ____ = Total____ inlbs			

RP-1

Seq #	Instructions	Date	Tech	Insp
3.12i	Each Solenoid Valve (30) should be attached to its respective mounting block using NAS1352N04-8 (38). Solenoid 1: 45i. Running____+ Applied: ____ = Total____ inlbs 46i. Running____+ Applied: ____ = Total____ inlbs Solenoid 2: 47i. Running____+ Applied: ____ = Total____ inlbs 48i. Running____+ Applied: ____ = Total____ inlbs Solenoid 3: 49i. Running____+ Applied: ____ = Total____ inlbs 50i. Running____+ Applied: ____ = Total____ inlbs			
3.13	Attach Oven Mounting Plate (7) to ribs using 8 NAS1189E3P16B (37) (Running torque should be 2-18 inlbs; Applied torque should be 67 ±7 inlbs) Oven Mounting Plate (7) to Large Computer Rib (3): 51. Running____+ Applied: ____ = Total____ inlbs 52. Running____+ Applied: ____ = Total____ inlbs Oven Mounting Plate (7) to Small Rib without Pin Puller (6): 53. Running____+ Applied: ____ = Total____ inlbs 54. Running____+ Applied: ____ = Total____ inlbs 55. Running____+ Applied: ____ = Total____ inlbs Oven Mounting Plate (7) to Small Rib with Pin Puller (5): 56. Running____+ Applied: ____ = Total____ inlbs 57. Running____+ Applied: ____ = Total____ inlbs 58. Running____+ Applied: ____ = Total____ inlbs			
3.14	Attach 1 Pipe Tee (34) to the Oven Mounting Plate (7) in each of the 3 locations below where the thermoplastic composite tubes will be			

Seq #	Instructions	Date	Tech	Insp
3.15	Bend tubing through tubing holes in Small Rib with Pin Puller (5) and Small Rib without Pin Puller (6) to connect Pipe Tee (34) to Solenoid Valve (30)			
3.16	Attach Large Rib (4) to Small Rib with Pin Puller (5) using 12 NAS1189E3P12B (36); Running torque should be 2-18 in lbs; Applied torque should be 66 ±7 inlbs 59. Running____+ Applied: ____ = Total____ inlbs 70. Running____+ Applied: ____ = Total____ inlbs 60. Running____+ Applied: ____ = Total____ inlbs 69. Running____+ Applied: ____ = Total____ inlbs 61. Running____+ Applied: ____ = Total____ inlbs 68. Running____+ Applied: ____ = Total____ inlbs 62. Running____+ Applied: ____ = Total____ inlbs 67. Running____+ Applied: ____ = Total____ inlbs 63. Running____+ Applied: ____ = Total____ inlbs 66. Running____+ Applied: ____ = Total____ inlbs 65. Running____+ Applied: ____ = Total____ inlbs 64. Running____+ Applied: ____ = Total____ inlbs			

Seq #	Instructions	Date	Tech	Insp
3.17	Attach Large Rib (4) to Small Rib without Pin Puller (6) using 12 NAS1189E3P12B (36); Running torque should be 2-18 in lbs; Applied torque should be 66 ±7 inlbs			
	71. Running____+ Applied: ____ = Total____ inlbs			
	82. Running____+ Applied: ____ = Total____ inlbs			
	72. Running____+ Applied: ____ = Total____ inlbs			
	81. Running____+ Applied: ____ = Total____ inlbs			
	73. Running____+ Applied: ____ = Total____ inlbs			
	80. Running____+ Applied: ____ = Total____ inlbs			
	74. Running____+ Applied: ____ = Total____ inlbs			
	79. Running____+ Applied: ____ = Total____ inlbs			
	75. Running____+ Applied: ____ = Total____ inlbs			
	78. Running____+ Applied: ____ = Total____ inlbs			
	76. Running____+ Applied: ____ = Total____ inlbs			
	77. Running____+ Applied: ____ = Total____ inlbs			
3.18	Attach Oven Mounting Plate (7) to Large Rib (4) using 2 NAS1189E3P16B (37) (Running torque should be 2-18 inlbs; Applied torque should be 67 ±7 inlbs)			
	83. Running____+ Applied: ____ = Total____ inlbs			
	84. Running____+ Applied: ____ = Total____ inlbs			
3.19	Bend tubing through tubing hole in Large Rib (4) to connect Pipe Tee (34) to Solenoid Valve (30)			

Seq #	Instructions	Date	Tech	Insp
3.20	Attach Pressure Transducer Mount to Bottom of Oven Plate (inside) (17) to bottom of Oven Mounting Plate (7) using NAS1189E3P12B (36). Running torque should be 2-18 in lbs; Applied torque should be 67 ±7 inlbs Mounting Block 1: 85. Running____+ Applied: ____ = Total____ inlbs 86. Running____+ Applied: ____ = Total____ inlbs Mounting Block 2: 87. Running____+ Applied: ____ = Total____ inlbs 88. Running____+ Applied: ____ = Total____ inlbs Mounting Block 3: 89. Running____+ Applied: ____ = Total____ inlbs 90. Running____+ Applied: ____ = Total____ inlbs **OMIT sequence 3.20 if the necessary parts are not available at the time of assembly.**			

Seq #	Instructions	Date	Tech	Insp
3.21	Attach 1 Pressure Transducer (21) to each of the three Pipe Tees (34) on the bottom of the Oven Mounting Plate (7) XDCR 1: Total____ inlbs XDCR 2: Total____ inlbs XDCR 3: Total____ inlbs – then secure each of them with the Pressure Transducer Mount to Bottom of Oven Plate (outside) (18) using NAS1189E3P12B (36): Running torque should be 2-18 in lbs; Applied torque should be 67 ±7 inlbs Mounting Block 1: 91. Running____+ Applied ____ = Total____ inlbs 92. Running____+ Applied ____ = Total____ inlbs Mounting Block 2: 93. Running____+ Applied ____ = Total____ inlbs 94. Running____+ Applied ____ = Total____ inlbs Mounting Block 3: 95. Running____+ Applied ____ = Total____ inlbs 96. Running____+ Applied ____ = Total____ inlbs **OMIT sequence 3.21 if the necessary parts are not available at the time of assembly.**			

Seq #	Instructions	Date	Tech	Insp
3.22	Slide the Pressure Transducer Mount to Ribs (inside) (19) down against each rib until lined up with thru-holes on rib for mounting block attachment. From inside the rib, attach each Pressure XDCR Mount to Ribs (inside) (19) to the rib using NAS1189E3P12B (36): Running torque should be 2-18 in lbs; Applied torque should be 66 ±7 inlbs Mounting Block 1: 97. Running____+ Applied ____ = Total____ inlbs 98. Running____+ Applied ____ = Total____ inlbs Mounting Block 2: 99. Running____+ Applied ____ = Total____ inlbs 100. Running____+ Applied ____ = Total____ inlbs Mounting Block 3: 101. Running____+ Applied ____ = Total____ inlbs 102. Running____+ Applied ____ = Total____ inlbs **OMIT sequence 3.22 if the necessary parts are not available at the time of assembly.**			

Seq #	Instructions	Date	Tech	Insp
3.23	Secure the Pressure Transducer (21) by securing the Pressure Transducer Mount to Ribs (outside) (20) to the Pressure XDCR Mount to Ribs (inside) (19) using NAS1189E3P12B (36): Running torque should be 2-18 in lbs; Applied torque should be 66 ±7 inlbs Mounting Block 1: 103. Running____+ Applied ____ = Total____ inlbs 104. Running____+ Applied ____ = Total____ inlbs Mounting Block 2: 105. Running____+ Applied ____ = Total____ inlbs 106. Running____+ Applied ____ = Total____ inlbs Mounting Block 3: 107. Running____+ Applied ____ = Total____ inlbs 108. Running____+ Applied ____ = Total____ inlbs **OMIT sequence 3.23 if the necessary parts are not available at the time of assembly.**			

Seq #	Instructions	Date	Tech	Insp
3.24	Attach Bottom Rectangle Plate (8) to the bottom of the four Ribs using 14 NAS1189E3P12B (36) Running torque should be 2-18 in lbs; Applied torque should be 67 ±7 inlbs 109. Running____+ Applied ____ = Total____ inlbs 110. Running____+ Applied ____ = Total____ inlbs 111. Running____+ Applied ____ = Total____ inlbs 112. Running____+ Applied ____ = Total____ inlbs 113. Running____+ Applied ____ = Total____ inlbs 114. Running____+ Applied ____ = Total____ inlbs 115. Running____+ Applied ____ = Total____ inlbs 116. Running____+ Applied ____ = Total____ inlbs 117. Running____+ Applied ____ = Total____ inlbs 118. Running____+ Applied ____ = Total____ inlbs 119. Running____+ Applied ____ = Total____ inlbs 120. Running____+ Applied ____ = Total____ inlbs 121. Running____+ Applied ____ = Total____ inlbs 122. Running____+ Applied ____ = Total____ inlbs			

All of the following parts are used in this assembly procedure:

Table 1: Wave #1 Parts

Item Number (per RD-6)	Quantity	Part Name (description)	Part Number	Serial or Lot Number
3	1	Large Computer Rib	RIGEX-2006-3	
4	1	Large Rib	RIGEX-2006-4	
5	1	Small Rib w/ Pin Puller	RIGEX-2006-5	
6	1	Small Rib w/o Pin Puller	RIGEX-2006-6	
7	1	Oven Mounting Plate	RIGEX-2006-7	
8	1	Bottom Rectangle Plate	RIGEX-2006-8	
9	1	Top Inflation Mounting Plate	RIGEX-2006-9	
10	1	Bottom Inflation Mounting Plate	RIGEX-2006-9	
17	3	Pressure Transducer Mount to Bottom of Oven Plate (inside) *may be omitted, see Seq. 3.21	RIGEX-2006-18	
18	3	Pressure Transducer Mount to Bottom of Oven Plate (outside) *may be omitted, see Seq. 3.21	RIGEX-2006-19	
19	3	Pressure Transducer Mount to Ribs (inside) *may be omitted, see Seq. 3.20	RIGEX-2006-21	
20	3	Pressure Transducer Mount to Ribs (outside) *may be omitted, see Seq. 3.20	RIGEX-2006-22	
21	6	Pressure Transducer		
25	3	Nitrogen Gas Tank		

Item Number (per RD-6)	Quantity	Part Name (description)	Part Number	Serial or Lot Number
26	A/R	Tubing		
27	3	Swagelok Fill Valve		
29	3	Solenoid Mounting Block	RIGEX-2006-20	
30	3	Solenoid Valve		
34	3	Pipe Tee		
35	A/R	Viton		
36	112	bolt	NAS1189E3P12B	
37	10	bolt	NAS1189E3P16B	
38	6	bolt	NAS1352N04-8	
41	A/R	Teflon Tape		

The following pictures may be used to help clarify the above assembly procedures. Each picture number corresponds to a particular step in the assembly procedure.

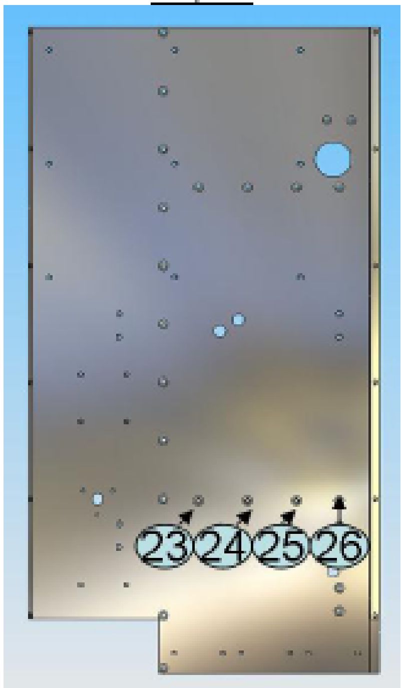
Seq. 3.1

Seq. 3.3

RP-1

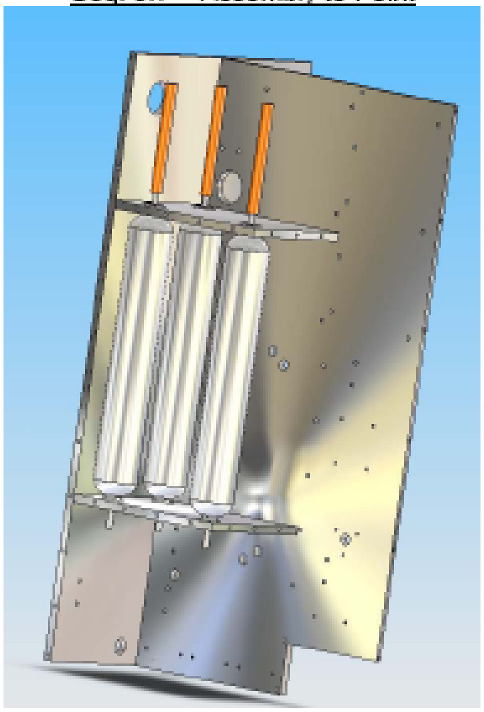
Seq. 3.5

Seq. 3.6

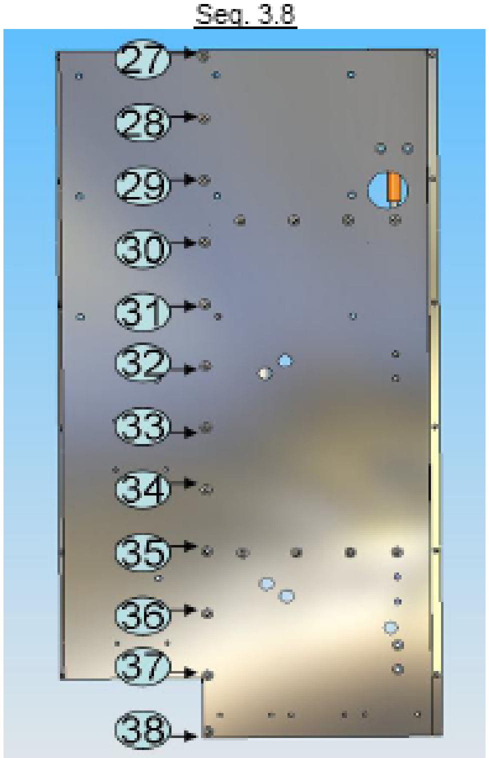


RP-1

Seq. 3.7 – Assembly to Point

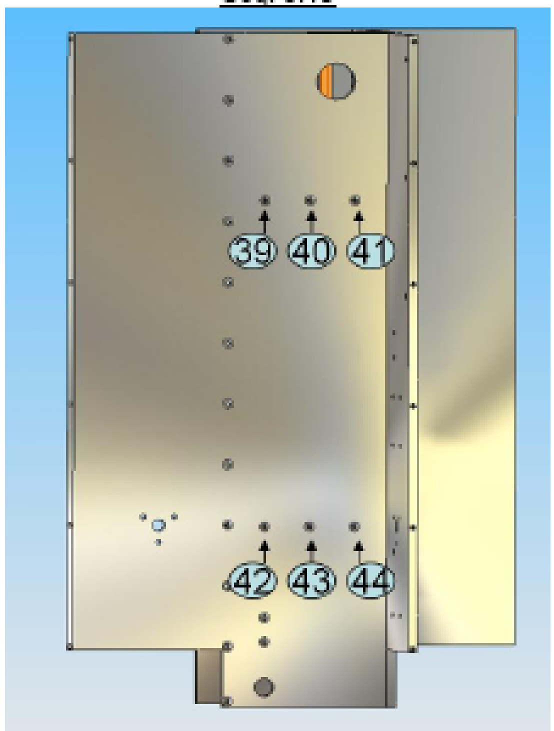


Seq. 3.8

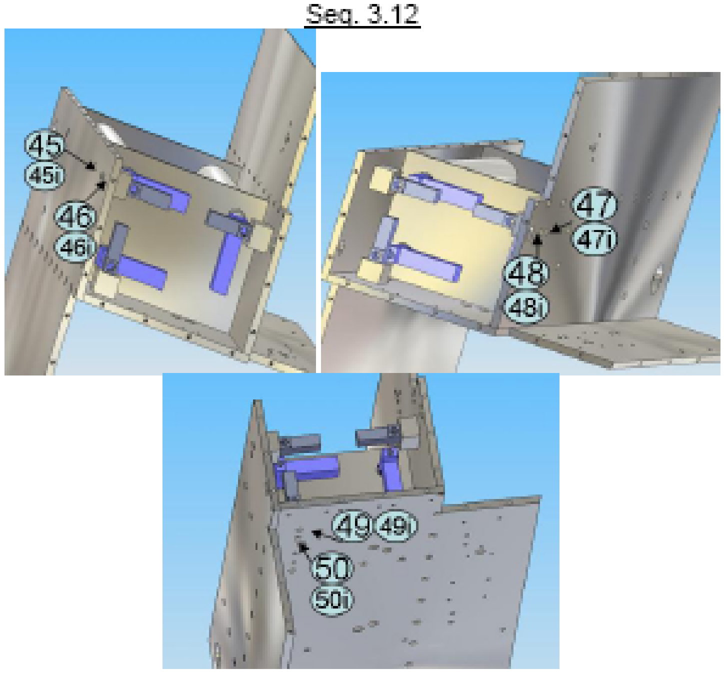


RP-1

Seq. 3.10



Seq. 3.12



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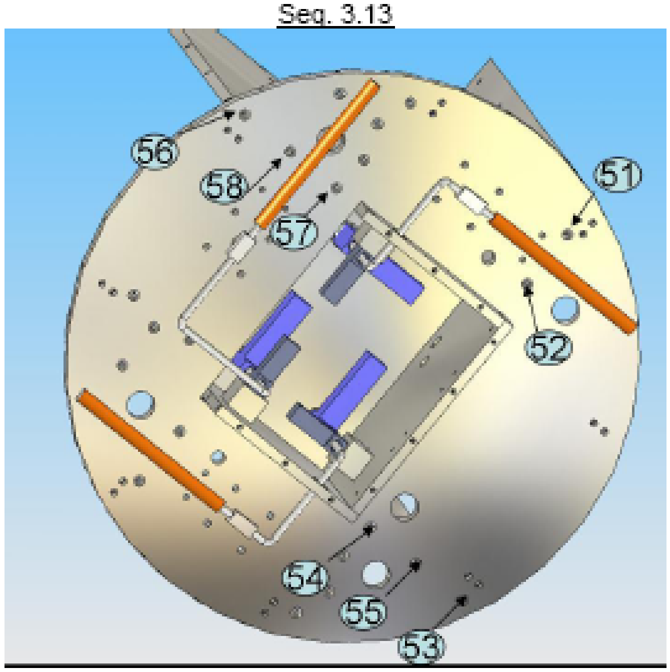
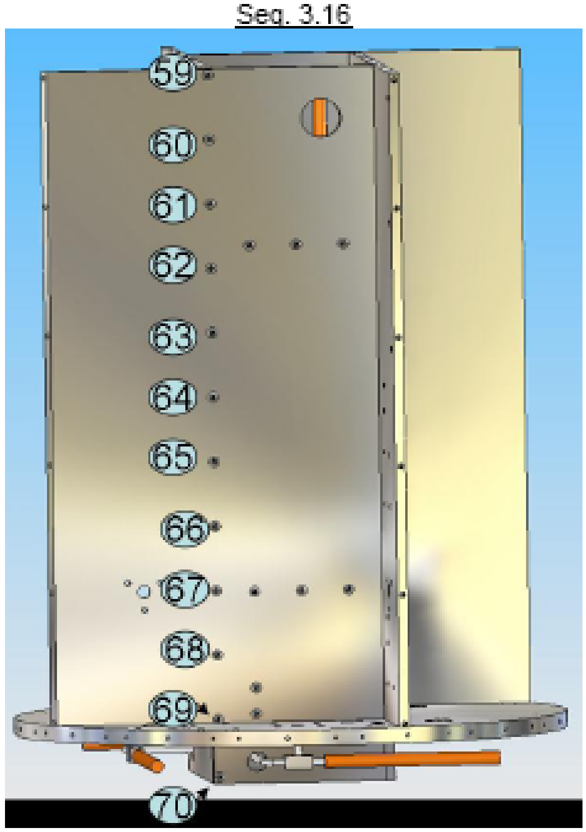
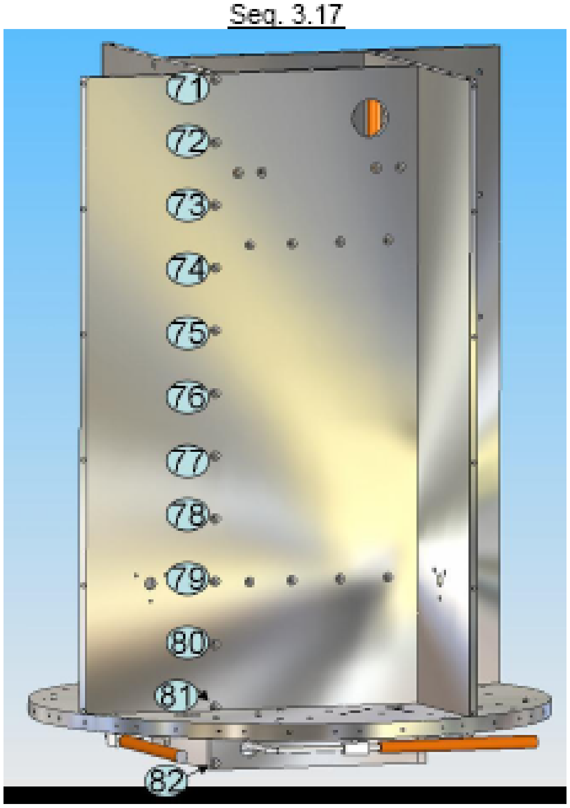


Seq. 3.16



RP-1

Seq. 3.17



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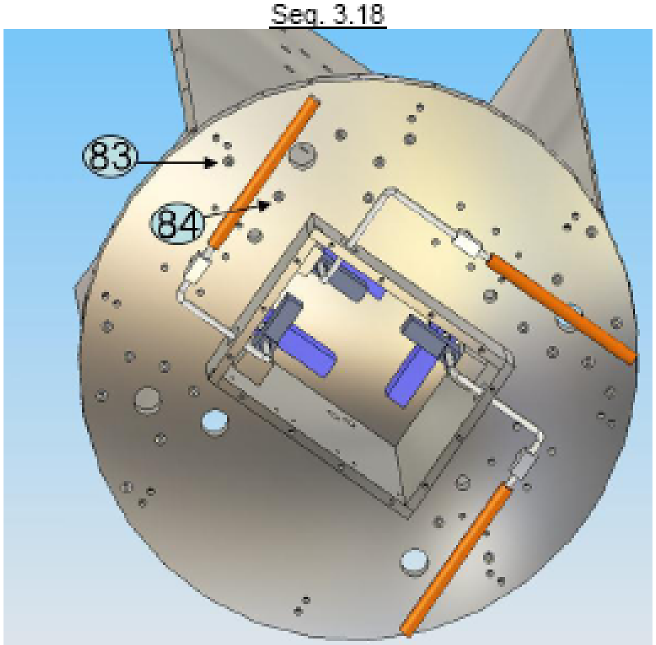
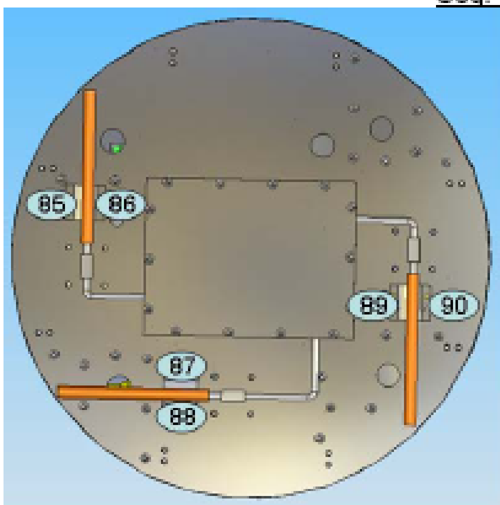
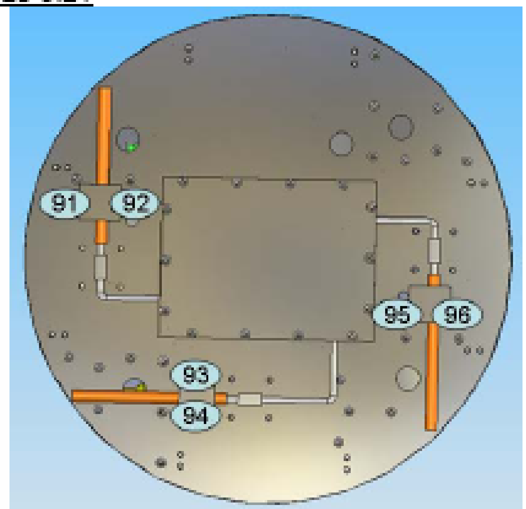


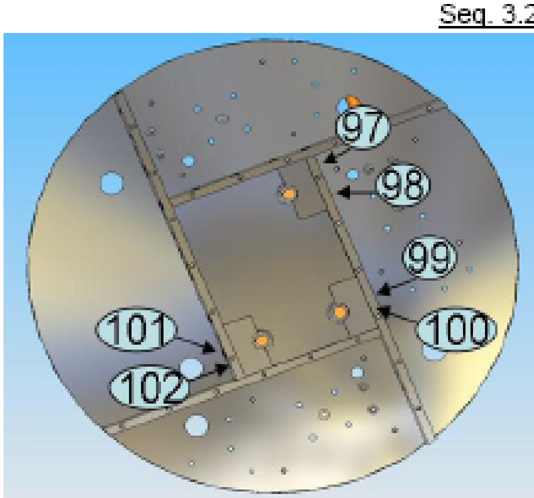
RP-1

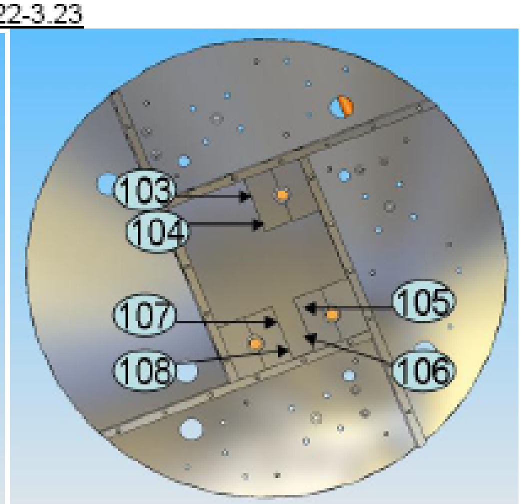
Seq. 3.20-3.21



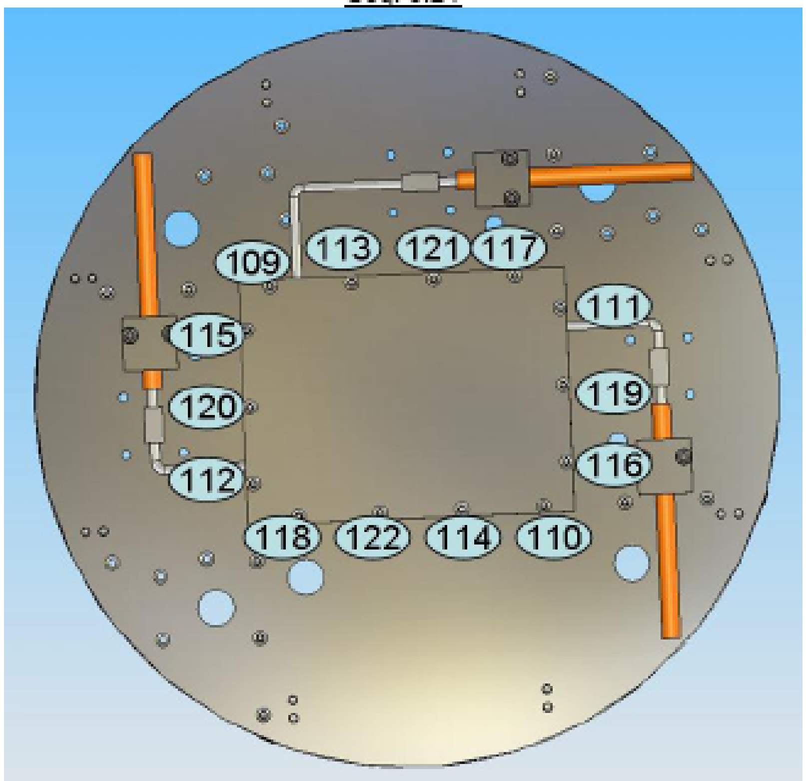


Seq. 3.22-3.23



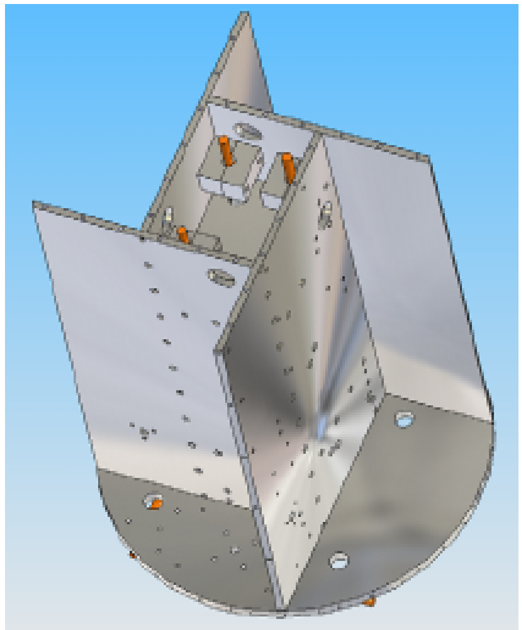


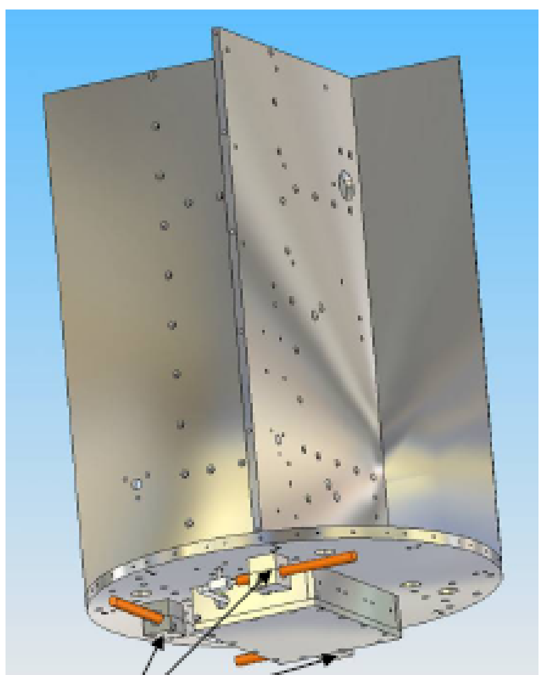
Seq. 3.24



RP-1

Seq. 3.25 – Assembly to Point





****Transducer mounting blocks shown here (Seq. #3.20-3.21) may or may not be installed during this assembly. This is dependent on the availability of the parts.**

Appendix B: Wave 2 Assembly (RP-1A)

The following appendix contains the second of three assembly procedures used in the construction of the RIGEX protoflight model. This assembly procedure describes in detail the second subassembly of RIGEX.

Air Force Institute of Technology
Wright Patterson Air Force Base

RIGEX
MECHANICAL ASSEMBLY PROCEDURE (RP-1A)

Prepared by:

____
BRADY O'NEAL, ENS, USN
AFIT/ENY

Approved by:

____
RICHARD COBB
RIGEX Principal Investigator
AFIT/ENY

Issue IR   Doc Serial No. RP-1A   Date 15-FEB-07

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CHANGE LOG				
Rev. Ltr. Change	Justification and Description of Change	Affected Pages	Release Date	Change Approval (*Initial & Date*)
IR	Initial Release	All	15-FEB-07	N/A

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Seq #	Instructions	Date	Tech	Insp
1.0	**Scope** This document provides step-by-step procedures for assembling the second sub-assembly of RIGEX.			
1.1	Assign Serial Number: _ RIGEX-WAVE2______			
2.0	**Materials and Components**			
2.1	Obtain parts and materials from Certified Stores. Item numbers (#) herein are referenced in Table 1 at the end of this document.			
2.2	Record each lot number or serial number in Table 1 at the end of these procedures.			
2.3	Record each part number in Table 1 at the end of these procedures.			

RP-1A

Seq #	Instructions	Date	Tech	Insp
2.4	Record Tool Information Tool No. ___________________ Last Calibration Date ________ Next Calibration Date ________ Tool No. ___________________ Last Calibration Date ________ Next Calibration Date ________ Tool No. ___________________ Last Calibration Date ________ Next Calibration Date ________ Torque values in this procedure will be as follows: Running torque – torque experienced by torque wrench before major resistance is met Applied torque – difference between Running and Total Torque Total Torque – maximum torque experienced by torque wrench (i.e. Total = Running + Applied)			

Seq #	Instructions	Date	Tech	Insp
3.0	**Inflation System Construction** NOTES: Before installing any bolts, apply alodine touch-up with swab stick to all threaded and unthreaded holes. Before applying torques, install all specified fasteners finger tight to ensure proper alignment. The pictures at the end of this document may be used to help clarify these assembly procedures. Each picture is labeled as a sequence number, and these sequence numbers correspond to a particular step in the assembly procedure.			
3.1	Attach Pressure Transducer Mount to Bottom of Oven Plate (inside) (17) to bottom of Oven Mounting Plate (7) using **NAS1189E3P12B** (36). Running torque should be 2-18 in lbs; Applied torque should be 67 ±7 inlbs Mounting Block 1: 85. Running____+ Applied: ____ = Total____ inlbs 86. Running____+ Applied: ____ = Total____ inlbs Mounting Block 2: 87. Running____+ Applied: ____ = Total____ inlbs 88. Running____+ Applied: ____ = Total____ inlbs Mounting Block 3: 89. Running____+ Applied: ____ = Total____ inlbs 90. Running____+ Applied: ____ = Total____ inlbs **OMIT sequence 3.1 if parts were previously installed in the first sub-assembly, RP-1.**			

Seq #	Instructions	Date	Tech	Insp
3.2	Attach 1 Pressure Transducer (21) to each of the three Pipe Tees (34) on the bottom of the Oven Mounting Plate (7) – then secure each of them with the Pressure Transducer Mount to Bottom of Oven Plate (outside) (18) using **NAS1189E3P12B** (36): Running torque should be 2-18 in lbs; Applied torque should be 67 ±7 inlbs Mounting Block 1: 91. Running____+ Applied ____ = Total____ inlbs 92. Running____+ Applied ____ = Total____ inlbs Mounting Block 2: 93. Running____+ Applied ____ = Total____ inlbs 94. Running____+ Applied ____ = Total____ inlbs Mounting Block 3: 95. Running____+ Applied ____ = Total____ inlbs 96. Running____+ Applied ____ = Total____ inlbs **OMIT sequence 3.2 if parts were previously installed in the first sub-assembly, RP-1.**			

Seq #	Instructions	Date	Tech	Insp
3.3	Slide the Pressure Transducer Mount to Ribs (inside) (19) down against each rib until lined up with thru-holes on rib for mounting block attachment. From inside the rib, attach each Pressure XDCR Mount to Ribs (inside) (19) to the rib using **NAS1189E3P12B** (36): Running torque should be 2-18 in lbs; Applied torque should be 66 ±7 inlbs Mounting Block 1: 97. Running____+ Applied ____ = Total____ inlbs 98. Running____+ Applied ____ = Total____ inlbs Mounting Block 2: 99. Running____+ Applied ____ = Total____ inlbs 100. Running____+ Applied ____ = Total____ inlbs Mounting Block 3: 101. Running____+ Applied ____ = Total____ inlbs 102. Running____+ Applied ____ = Total____ inlbs **OMIT sequence 3.3 if parts were previously installed in the first sub-assembly, RP-1.**			
3.4	Secure the Pressure Transducer (21) by securing the Pressure Transducer Mount to Ribs (outside) (20) to the Pressure XDCR Mount to Ribs (inside) (19) using **NAS1189E3P12B** (36): Running torque should be 2-18 in lbs; Applied torque should be 66 ±7 inlbs Mounting Block 1: 103. Running____+ Applied ____ = Total____ inlbs 104. Running____+ Applied ____ = Total____ inlbs Mounting Block 2: 105. Running____+ Applied ____ = Total____ inlbs 106. Running____+ Applied ____ = Total____ inlbs Mounting Block 3: 107. Running____+ Applied ____ = Total____ inlbs 108. Running____+ Applied ____ = Total____ inlbs **OMIT sequence 3.4 if the necessary parts are not available at the time of assembly.**			

RP-1A

Seq #	Instructions	Date	Tech	Insp
4.0	**Experiment Bay Construction**			
4.1	Attach 3 Oven Assemblies (22) to Oven Mounting Plate (7). Ovens are already built using non-NAS fasteners and has passed a fail-safe that it will not become a fracture hazard. Each oven will be attached using 4 **NAS1189E3P12B** (36) bolts: Running torque should be 2-18 in lbs; Applied torque should be 66 ±7 inlbs Oven 1: 123. Running____+ Applied: ____ = Total____ inlbs 124. Running____+ Applied: ____ = Total____ inlbs 125. Running____+ Applied: ____ = Total____ inlbs 126. Running____+ Applied: ____ = Total____ inlbs Oven 2: 127. Running____+ Applied: ____ = Total____ inlbs 128. Running____+ Applied: ____ = Total____ inlbs 129. Running____+ Applied: ____ = Total____ inlbs 130. Running____+ Applied: ____ = Total____ inlbs Oven 3: 131. Running____+ Applied: ____ = Total____ inlbs 132. Running____+ Applied: ____ = Total____ inlbs 133. Running____+ Applied: ____ = Total____ inlbs 134. Running____+ Applied: ____ = Total____ inlbs			

RP-1A

Seq #	Instructions	Date	Tech	Insp
4.2	Attach Oven Bracket Piece 1 (11) to Oven Bracket Piece 2 (12) using 3 **NAS1189E3P12B** (36): Running torque should be 2-18 in lbs; Applied torque should be 66 ±7 inlbs. Repeat for each of the 3 Oven Mounting Brackets. Mounting Bracket 1: 135. Running____+ Applied: ____ = Total____ inlbs 136. Running____+ Applied: ____ = Total____ inlbs 137. Running____+ Applied: ____ = Total____ inlbs Mounting Bracket 2: 138. Running____+ Applied: ____ = Total____ inlbs 139. Running____+ Applied: ____ = Total____ inlbs 140. Running____+ Applied: ____ = Total____ inlbs Mounting Bracket 3: 141. Running____+ Applied: ____ = Total____ inlbs 142. Running____+ Applied: ____ = Total____ inlbs 143. Running____+ Applied: ____ = Total____ inlbs			
4.3	Attach Oven Latch Hinge (39) to Oven Bracket Piece 2 (12) using 2 **NAS1291C04M** locknuts (40), 2 **NAS1352N04-8 bolts** (38) and 2 **NAS620C4** washers (42). Repeat for each of the 3 Oven Mounting Brackets. Running torque should be 0-80 in-oz; Applied torque should be 112-140 in-oz. Hinge 1: 144. Running____+ Applied: ____ = Total____ inlbs 145. Running____+ Applied: ____ = Total____ inlbs Hinge 2: 146. Running____+ Applied: ____ = Total____ inlbs 147. Running____+ Applied: ____ = Total____ inlbs Hinge 3: 148. Running____+ Applied: ____ = Total____ inlbs 149. Running____+ Applied: ____ = Total____ inlbs			

Seq #	Instructions	Date	Tech	Insp
4.4	Attach Oven Latch (13) to Oven Latch Hinge (35) using 2 **NAS1291C04M** locknuts (40), 2 **NAS1352N04-8** bolts (41) and 2 **NAS620C4** washers (42). Repeat for each of the 3 Oven Latches. Running torque should be 0-80 in-oz; Applied torque should be 112-140 in-oz. Hinge 1: 150. Running____+ Applied: ____ = Total____ inlbs 151. Running____+ Applied: ____ = Total____ inlbs Hinge 2: 152. Running____+ Applied: ____ = Total____ inlbs 153. Running____+ Applied: ____ = Total____ inlbs Hinge 3: 154. Running____+ Applied: ____ = Total____ inlbs 155. Running____+ Applied: ____ = Total____ inlbs			

RP-1A

Seq #	Instructions	Date	Tech	Insp
4.5	Attach Oven Bracket Pieces 1&2 (11,12) to Oven Mounting Plate (7) using 4 **NAS1189E3P16B** (37): Running torque should be 2-18 in lbs; Applied torque should be 66 ±7 inlbs. Repeat for each of the 3 Oven Brackets. Mounting Bracket 1: 156. Running____+ Applied: ____ = Total____ inlbs 157. Running____+ Applied: ____ = Total____ inlbs 158. Running____+ Applied: ____ = Total____ inlbs 159. Running____+ Applied: ____ = Total____ inlbs Mounting Bracket 2: 160. Running____+ Applied: ____ = Total____ inlbs 161. Running____+ Applied: ____ = Total____ inlbs 162. Running____+ Applied: ____ = Total____ inlbs 163. Running____+ Applied: ____ = Total____ inlbs Mounting Bracket 3: 164. Running____+ Applied: ____ = Total____ inlbs 165. Running____+ Applied: ____ = Total____ inlbs 166. Running____+ Applied: ____ = Total____ inlbs 167. Running____+ Applied: ____ = Total____ inlbs			
4.6	Apply Braycote O-Ring Grease (43) to the Oven Mounting Plate (7) at the 3 expected locations of the L'Guarde Tubes			
4.7	Install a Viton O-Ring (44) at the 3 expected locations of the L'Guarde Tubes			

Seq #	Instructions	Date	Tech	Insp
4.8	Install a L'Guarde Tube (23) using **NAS1351N4-24** bolts (45), **NAS620C416** washers (46) and **NAS1291C4M** locknuts (47) - Do not use flight tubes until ready for flight! Running torque should be 3-30 in lbs; Applied torque should be 157 ±16 inlbs. Tube 1: 168. Running____+ Applied: ____ = Total____ inlbs 169. Running____+ Applied: ____ = Total____ inlbs 170. Running____+ Applied: ____ = Total____ inlbs 171. Running____+ Applied: ____ = Total____ inlbs Tube 2: 172. Running____+ Applied: ____ = Total____ inlbs 173. Running____+ Applied: ____ = Total____ inlbs 174. Running____+ Applied: ____ = Total____ inlbs 175. Running____+ Applied: ____ = Total____ inlbs Tube 3: 176. Running____+ Applied: ____ = Total____ inlbs 177. Running____+ Applied: ____ = Total____ inlbs 178. Running____+ Applied: ____ = Total____ inlbs 179. Running____+ Applied: ____ = Total____ inlbs			

Seq #	Instructions	Date	Tech	Insp
4.9	Attach a pin puller (31) to the Large Computer Rib (3), Large Rib (4) and the Small Rib with Pin Puller (5). Orient them so that the pin is facing into each experiment bay. Use **NAS1291C04M** locknuts (40), **NAS1352N04-10** bolts (48) and **NAS620C4** washers (42). Running torque should be 0-80 in-oz; Applied torque should be 112-140 in-oz. Pin Puller 1: 150. Running____+ Applied: ____ = Total____ inlbs 151. Running____+ Applied: ____ = Total____ inlbs 151. Running____+ Applied: ____ = Total____ inlbs Pin Puller 2: 152. Running____+ Applied: ____ = Total____ inlbs 153. Running____+ Applied: ____ = Total____ inlbs 151. Running____+ Applied: ____ = Total____ inlbs Pin Puller 3: 154. Running____+ Applied: ____ = Total____ inlbs 155. Running____+ Applied: ____ = Total____ inlbs 151. Running____+ Applied: ____ = Total____ inlbs			

Seq #	Instructions	Date	Tech	Insp
5.0	**Computer Bay Assembly**			
5.1	Attach Computer Container (33) to Computer Mounting Plate (32) using **NAS1351N4-12** bolts (49), **NAS1291C4M** locknuts (47) and **NAS620C416** washers (46) Running torque should be 3-30 in lbs; Applied torque should be 157 ±16 inlbs. 189. Running____+ Applied: ____ = Total____ inlbs 190. Running____+ Applied: ____ = Total____ inlbs 191. Running____+ Applied: ____ = Total____ inlbs 192. Running____+ Applied: ____ = Total____ inlbs			
5.2	Attach Computer Mounting Plate (32) to Large Computer Rib (3) using **NAS1189E3P8B** bolts (50) and MS21209F1-20L Heli-Coil inserts (installed during fabrication). Running torque should be 2-18 in lbs; Applied torque should be 66 ±7 inlbs. 193. Running____+ Applied: ____ = Total____ inlbs 194. Running____+ Applied: ____ = Total____ inlbs 195. Running____+ Applied: ____ = Total____ inlbs 196. Running____+ Applied: ____ = Total____ inlbs 197. Running____+ Applied: ____ = Total____ inlbs 198. Running____+ Applied: ____ = Total____ inlbs 199. Running____+ Applied: ____ = Total____ inlbs 200. Running____+ Applied: ____ = Total____ inlbs			

Seq #	Instructions	Date	Tech	Insp
5.3	Attach Power Distribution Plate (28) to Large Computer Rib (3) using **NAS1189E3P8B** bolts (50) and MS21209F1-20L Heli-Coil inserts (installed during fabrication) Running torque should be 2-18 in lbs; Applied torque should be 66 ±7 inlbs. 201. Running____+ Applied: ____ = Total____ inlbs 202. Running____+ Applied: ____ = Total____ inlbs 203. Running____+ Applied: ____ = Total____ inlbs 204. Running____+ Applied: ____ = Total____ inlbs 205. Running____+ Applied: ____ = Total____ inlbs 206. Running____+ Applied: ____ = Total____ inlbs 207. Running____+ Applied: ____ = Total____ inlbs 208. Running____+ Applied: ____ = Total____ inlbs 209. Running____+ Applied: ____ = Total____ inlbs			

Seq #	Instructions	Date	Tech	Insp
6.0	**Experiment Top Plate**			
6.1	Attach Experiment Top Plate (2) to the tops of the 4 Ribs using 24 **NAS1351N3LB16** bolts (51) and **NAS1587A3C** washers (52). Lubricate each bolt with Braycote grease (53). Running torque should be 2-18 inlbs; Applied torque should be 33 ±5 inlbs 210. Running____+ Applied: ____ = Total____ inlbs 211. Running____+ Applied: ____ = Total____ inlbs 212. Running____+ Applied: ____ = Total____ inlbs 213. Running____+ Applied: ____ = Total____ inlbs 214. Running____+ Applied: ____ = Total____ inlbs 215. Running____+ Applied: ____ = Total____ inlbs 216. Running____+ Applied: ____ = Total____ inlbs 217. Running____+ Applied: ____ = Total____ inlbs 218. Running____+ Applied: ____ = Total____ inlbs 219. Running____+ Applied: ____ = Total____ inlbs 220. Running____+ Applied: ____ = Total____ inlbs 221. Running____+ Applied: ____ = Total____ inlbs 222. Running____+ Applied: ____ = Total____ inlbs 223. Running____+ Applied: ____ = Total____ inlbs 224. Running____+ Applied: ____ = Total____ inlbs 225. Running____+ Applied: ____ = Total____ inlbs 226. Running____+ Applied: ____ = Total____ inlbs 227. Running____+ Applied: ____ = Total____ inlbs 228. Running____+ Applied: ____ = Total____ inlbs 229. Running____+ Applied: ____ = Total____ inlbs 230. Running____+ Applied: ____ = Total____ inlbs 231. Running____+ Applied: ____ = Total____ inlbs 232. Running____+ Applied: ____ = Total____ inlbs 233. Running____+ Applied: ____ = Total____ inlbs			

RP-1A

All of the following parts are used in this assembly procedure:

Table 1: Wave #1 Parts

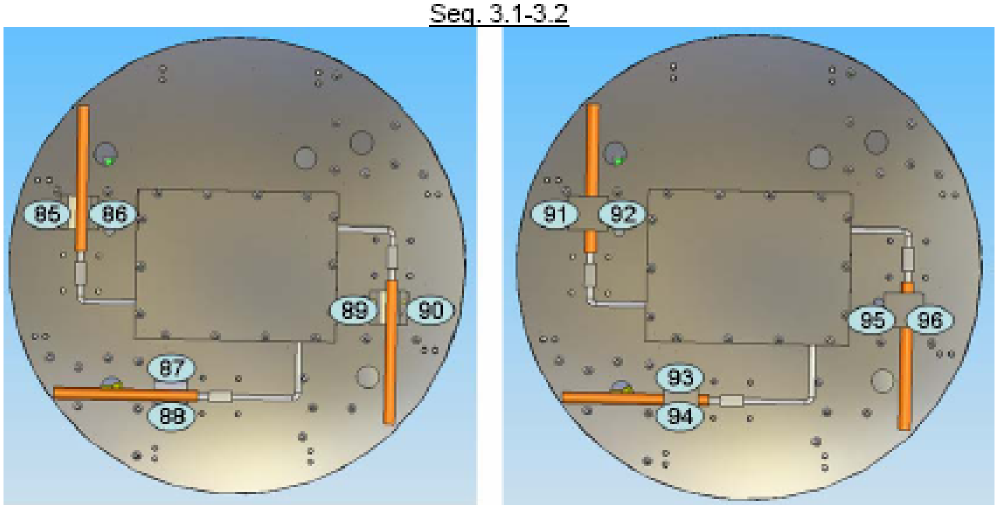
Item Number (per RD-6)	Quantity	Part Name (description)	Part Number	Serial or Lot Number
2	1	Experiment Top Plate	RIGEX-2006-2	
3	1	Large Computer Rib	RIGEX-2006-3	
4	1	Large Rib	RIGEX-2006-4	
5	1	Small Rib w/ Pin Puller	RIGEX-2006-5	
6	1	Small Rib w/o Pin Puller	RIGEX-2006-6	
7	1	Oven Mounting Plate	RIGEX-2006-7	
11	3	Oven Bracket Piece 1	RIGEX-2006-10	
12	3	Oven Bracket Piece 2	RIGEX-2006-11	
13	3	Oven Latch	RIGEX-2006-12	
17	3	Pressure Transducer Mount to Bottom of Oven Plate (inside) *may be omitted, see Seq. 3.21	RIGEX-2006-18	
18	3	Pressure Transducer Mount to Bottom of Oven Plate (outside) *may be omitted, see Seq. 3.21	RIGEX-2006-19	
19	3	Pressure Transducer Mount to Ribs (inside) *may be omitted, see Seq. 3.20	RIGEX-2006-21	
20	3	Pressure Transducer Mount to Ribs (outside) *may be omitted, see Seq. 3.20	RIGEX-2006-22	
22	3	Oven Assembly		
23	3	L'Guarde Tube		
31	3	Pin Puller		
32	2	Computer Mounting Plate		

RP-1A

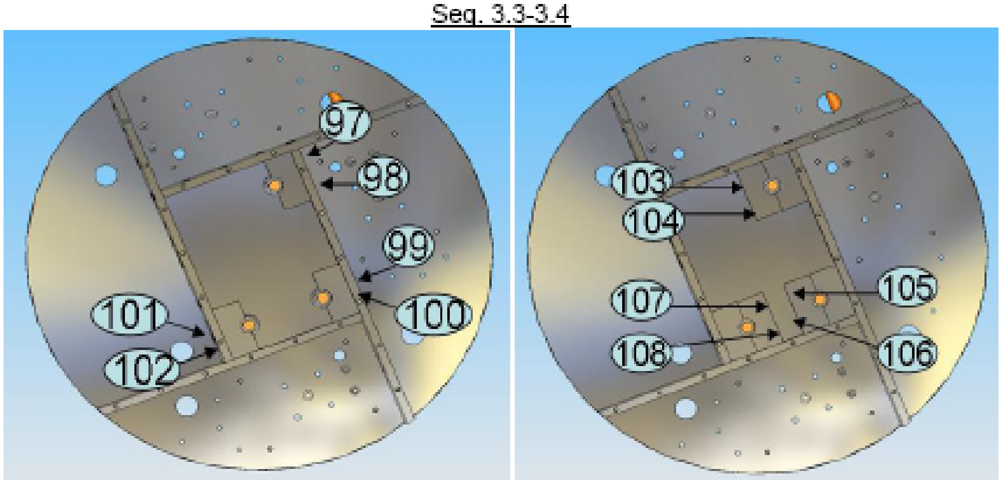
Item Number (per RD-6)	Quantity	Part Name (description)	Part Number	Serial or Lot Number
33	1	Computer Container		
36	45	bolt	NAS1189E3P12B	
37	12	bolt	NAS1189E3P16B	
38	12	bolt	NAS1352N04-8	
39	3	Oven Latch Hinge		
40	21	locknut	NAS1291C04M	
42	66	washer	NAS620C4	
43	A/R	O-Ring Grease		
44	3	O-Ring		
45	12	bolt	NAS1351N4-24	
46	28	washer	NAS620C416	
47	16	locknut	NAS1291C4M	
48	9	bolt	NAS1352N04-10	
49	4	bolt	NAS1351N4-12	
50	17	bolt	NAS1189E3P8B	
51	24	bolt	NAS1351N3LB16	
52	24	washer	NAS1587A3C	
53	A/R	Braycote thread grease	TBD	

The following pictures may be used to help clarify the above assembly procedures. Each picture number corresponds to a particular step in the assembly procedure.

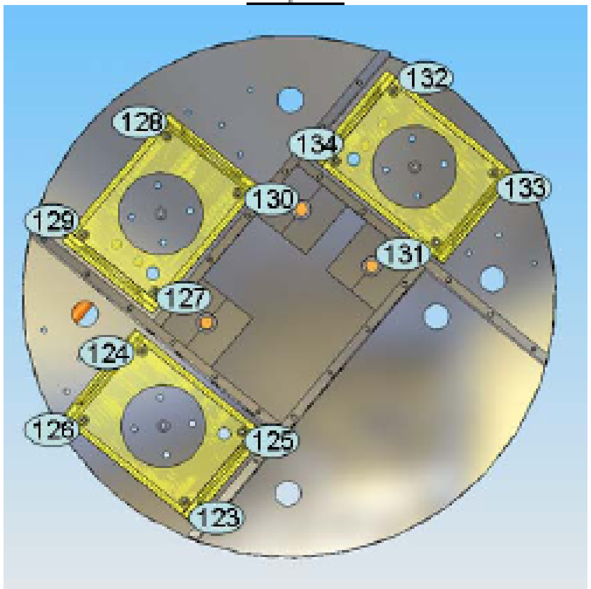
Seq. 3.1-3.2



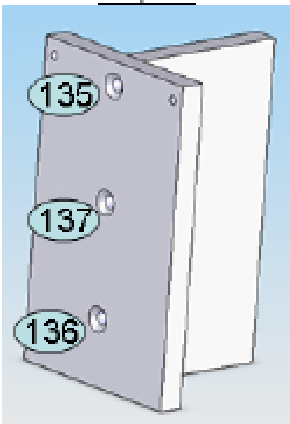
Seq. 3.3-3.4



Seq. 4.1

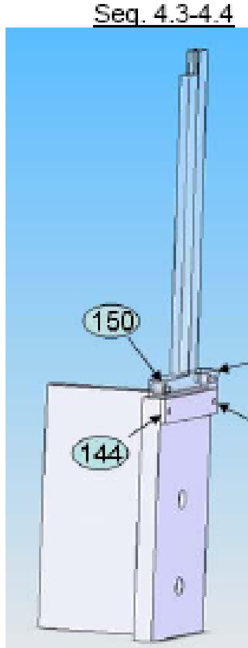


Seq. 4.2

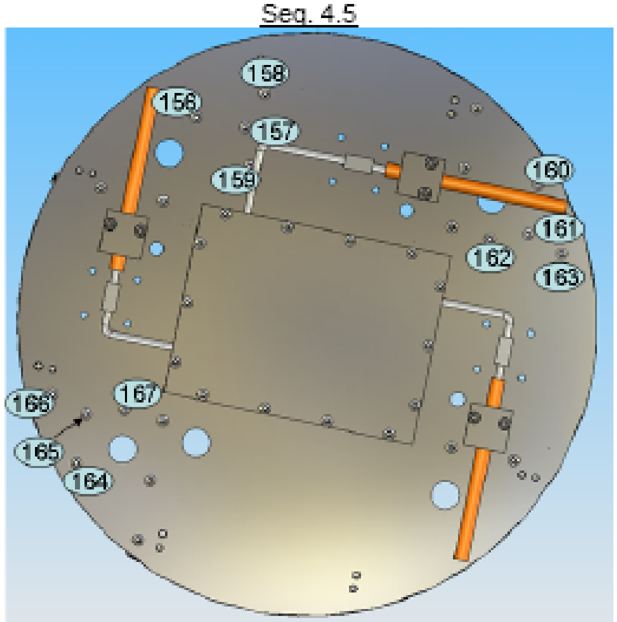


RP-1A

Seq. 4.3-4.4

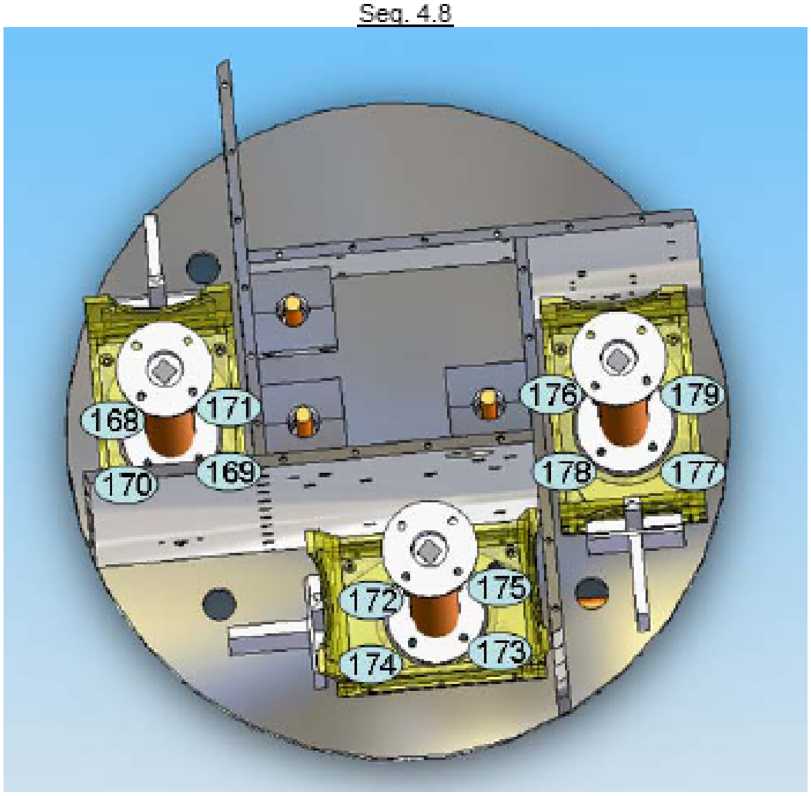


Seq. 4.5



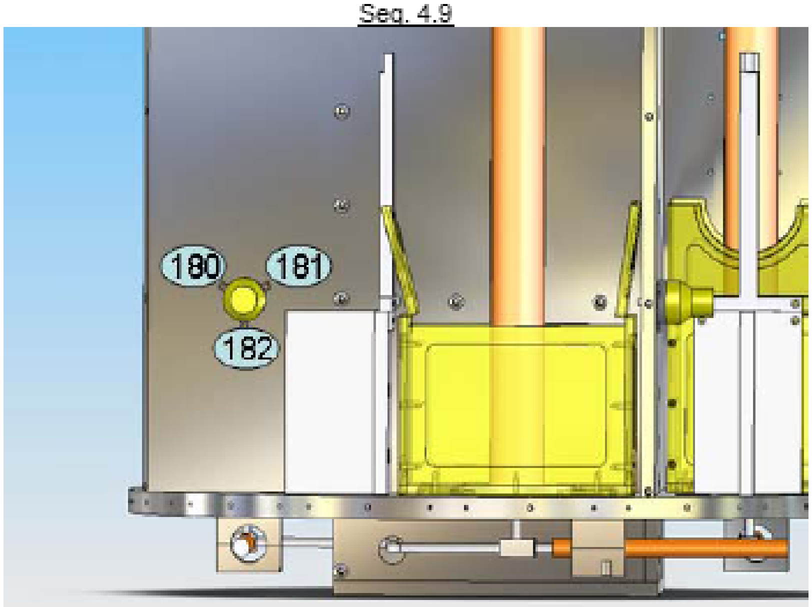
RP-1A

Seq. 4.8

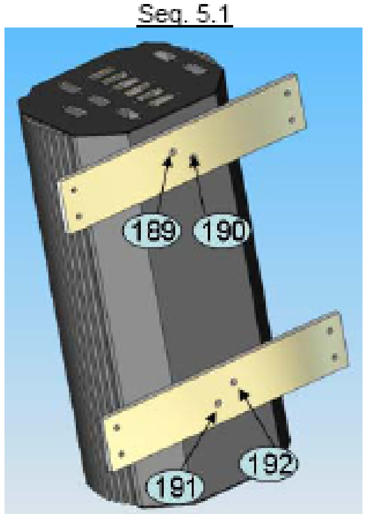


RP-1A

Seq. 4.9

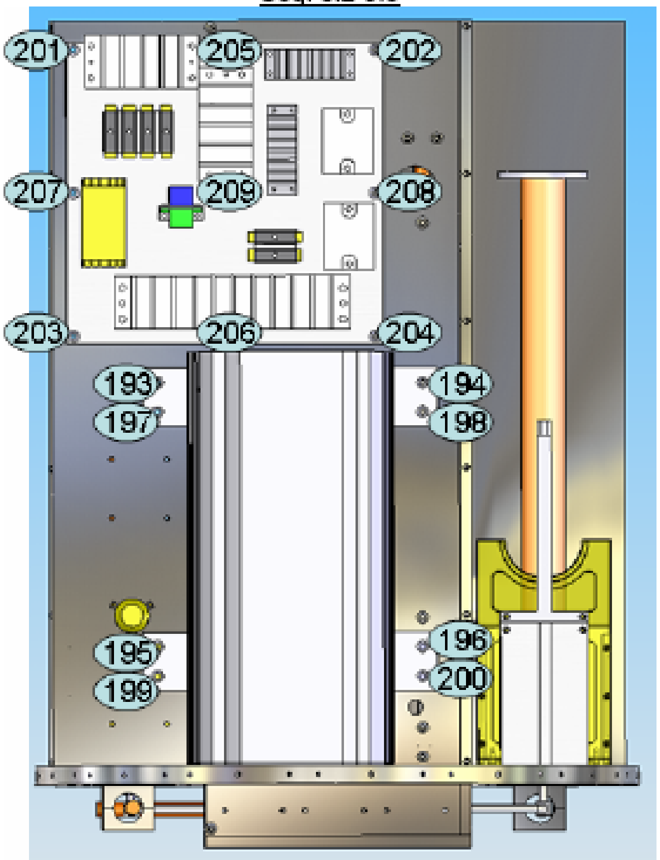


Seq. 5.1



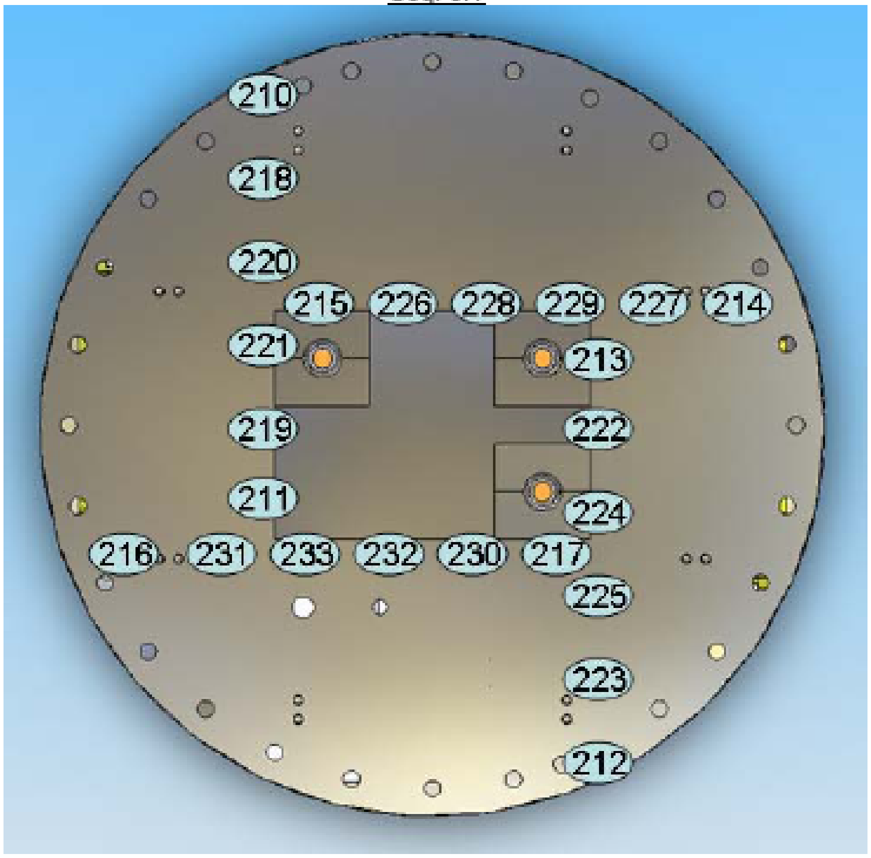
RP-1A

Seq. 5.2-5.3



RP-1A

Seq. 6.1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RP-1A

Appendix C: Wave 3 Assembly (RP-1B)

The following appendix contains the third of three assembly procedures used in the construction of the RIGEX protoflight model. This assembly procedure describes in detail the third and final subassembly of RIGEX. All components installed in this assembly procedure use Heli-coils for fastening the various components.

Air Force Institute of Technology
Wright Patterson Air Force Base

RIGEX
MECHANICAL ASSEMBLY PROCEDURE (RP-1B)

Prepared by:

____
BRADY O'NEAL, ENS, USN
AFIT/ENY

Approved by:

____
RICHARD COBB
RIGEX Principal Investigator
AFIT/ENY

Issue IR   Doc Serial No. RP-1B   Date 01-APR-07

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CHANGE LOG				
Rev. Ltr. Change	Justification and Description of Change	Affected Pages	Release Date	Change Approval (*Initial & Date*)
IR	Initial Release	All	01-APR-07	N/A

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Seq #	Instructions	Date	Tech	Insp
1.0	**Scope** This document provides step-by-step procedures for assembling the third sub-assembly of RIGEX.			
1.1	Assign Serial Number: _ RIGEX-WAVE3________			
2.0	**Materials and Components**			
2.1	Obtain parts and materials from Certified Stores. Item numbers (#) herein are referenced in Table 1 at the end of this document.			
2.2	Record each lot number or serial number in Table 1 at the end of these procedures.			
2.3	Record each part number in Table 1 at the end of these procedures.			

RP-1B

Seq #	Instructions	Date	Tech	Insp
2.4	Record Tool Information Tool No. ___________________ Last Calibration Date _________ Next Calibration Date ________ Tool No. ___________________ Last Calibration Date _________ Next Calibration Date ________ Tool No. ___________________ Last Calibration Date _________ Next Calibration Date ________ Torque values in this procedure will be as follows: Running torque – torque experienced by torque wrench before major resistance is met Applied torque – difference between Running and Total Torque Total Torque – maximum torque experienced by torque wrench (i.e. Total = Running + Applied)			

RP-1B

Seq #	Instructions	Date	Tech	Insp
3.0	**Shroud Attachment**			
3.1	Before positioning the Shroud (55) over the RIGEX structure, install the 6 Shroud Seam Brackets (54) on the inside of one edge of the Shroud seam using 6 **NAS8402-7** bolts (57). Ensure that the Shroud Seam Brackets are square with the shroud seam after applying torque. Running torque should be 1.5-11 inlbs; Applied torque should be 40 ± 4 inlbs 234. Running____+ Applied: ____ = Total____ inlbs 235. Running____+ Applied: ____ = Total____ inlbs 236. Running____+ Applied: ____ = Total____ inlbs 237. Running____+ Applied: ____ = Total____ inlbs 238. Running____+ Applied: ____ = Total____ inlbs 239. Running____+ Applied: ____ = Total____ inlbs			
3.2	Slide the Shroud (55) over RIGEX structure. Position the seam of the Shroud over the computer bay area. Ensure that the six Shroud Seam Brackets (54) are square with the seam of the shroud.			

RP-1B

Seq #	Instructions	Date	Tech	Insp
3.3	Secure the Shroud Seam Brackets (54) to the adjacent edge of the Shroud (55) by installing 6 **NAS8402-7** bolts (57). Ensure that the edges of the Shroud are flush, and that the remaining shroud attachment holes are aligned with the holes in the rest of the structure. Running torque should be 1.5-11 inlbs; Applied torque should be 40 ± 4 inlbs 240. Running____+ Applied: ____ = Total____ inlbs 241. Running____+ Applied: ____ = Total____ inlbs 242. Running____+ Applied: ____ = Total____ inlbs 243. Running____+ Applied: ____ = Total____ inlbs 244. Running____+ Applied: ____ = Total____ inlbs 245. Running____+ Applied: ____ = Total____ inlbs			
3.4	Insert and finger-tighten 52 **NAS8402-7** bolts (57) into the shroud bolt holes. Be sure to use the Angled Washers (59) on all shroud-to-rib interface locations.			

RP-1B

Seq #	Instructions	Date	Tech	Insp
3.5	Using a crossing pattern, torque all shroud bolts Running torque should be 1.5-11 inlbs; Applied torque should be 40 ± 4 inlbs 246. Running____+ Applied: ____ = Total____ inlbs 247. Running____+ Applied: ____ = Total____ inlbs 248. Running____+ Applied: ____ = Total____ inlbs 249. Running____+ Applied: ____ = Total____ inlbs 250. Running____+ Applied: ____ = Total____ inlbs 251. Running____+ Applied: ____ = Total____ inlbs 252. Running____+ Applied: ____ = Total____ inlbs 253. Running____+ Applied: ____ = Total____ inlbs 254. Running____+ Applied: ____ = Total____ inlbs 255. Running____+ Applied: ____ = Total____ inlbs 256. Running____+ Applied: ____ = Total____ inlbs 257. Running____+ Applied: ____ = Total____ inlbs 258. Running____+ Applied: ____ = Total____ inlbs 259. Running____+ Applied: ____ = Total____ inlbs 260. Running____+ Applied: ____ = Total____ inlbs 261. Running____+ Applied: ____ = Total____ inlbs 262. Running____+ Applied: ____ = Total____ inlbs 263. Running____+ Applied: ____ = Total____ inlbs 264. Running____+ Applied: ____ = Total____ inlbs 265. Running____+ Applied: ____ = Total____ inlbs 266. Running____+ Applied: ____ = Total____ inlbs 267. Running____+ Applied: ____ = Total____ inlbs 268. Running____+ Applied: ____ = Total____ inlbs 269. Running____+ Applied: ____ = Total____ inlbs 270. Running____+ Applied: ____ = Total____ inlbs 271. Running____+ Applied: ____ = Total____ inlbs 272. Running____+ Applied: ____ = Total____ inlbs 273. Running____+ Applied: ____ = Total____ inlbs			

RP-1B

Seq #	Instructions	Date	Tech	Insp
3.5				
(cont)	274. Running____+ Applied: ____ = Total____ inlbs			
	275. Running____+ Applied: ____ = Total____ inlbs			
	276. Running____+ Applied: ____ = Total____ inlbs			
	277. Running____+ Applied: ____ = Total____ inlbs			
	278. Running____+ Applied: ____ = Total____ inlbs			
	279. Running____+ Applied: ____ = Total____ inlbs			
	280. Running____+ Applied: ____ = Total____ inlbs			
	281. Running____+ Applied: ____ = Total____ inlbs			
	282. Running____+ Applied: ____ = Total____ inlbs			
	283. Running____+ Applied: ____ = Total____ inlbs			
	284. Running____+ Applied: ____ = Total____ inlbs			
	285. Running____+ Applied: ____ = Total____ inlbs			
	286. Running____+ Applied: ____ = Total____ inlbs			
	287. Running____+ Applied: ____ = Total____ inlbs			
	288. Running____+ Applied: ____ = Total____ inlbs			
	289. Running____+ Applied: ____ = Total____ inlbs			
	290. Running____+ Applied: ____ = Total____ inlbs			
	291. Running____+ Applied: ____ = Total____ inlbs			
	292. Running____+ Applied: ____ = Total____ inlbs			
	293. Running____+ Applied: ____ = Total____ inlbs			
	294. Running____+ Applied: ____ = Total____ inlbs			
	295. Running____+ Applied: ____ = Total____ inlbs			
	296. Running____+ Applied: ____ = Total____ inlbs			
	297. Running____+ Applied: ____ = Total____ inlbs			
	298. Running____+ Applied: ____ = Total____ inlbs			
	299. Running____+ Applied: ____ = Total____ inlbs			

RP-1B

Seq #	Instructions	Date	Tech	Insp
4.0	**Cape Mounting Plate Attachment**			
4.1	Attach CAPE Mounting Plate (1) to Experiment Top Plate (2) using 28 MS21209F6-15L Heli-Coil Inserts (installed during fabrication) and **NAS1351N6-20** bolts (58). Running torque should be 9.5 - 80 inlbs; Applied torque should be 536 ± 27 inlbs 300. Running____+ Applied: ____ = Total____ inlbs 301. Running____+ Applied: ____ = Total____ inlbs 302. Running____+ Applied: ____ = Total____ inlbs 303. Running____+ Applied: ____ = Total____ inlbs 304. Running____+ Applied: ____ = Total____ inlbs 305. Running____+ Applied: ____ = Total____ inlbs 306. Running____+ Applied: ____ = Total____ inlbs 307. Running____+ Applied: ____ = Total____ inlbs 308. Running____+ Applied: ____ = Total____ inlbs 309. Running____+ Applied: ____ = Total____ inlbs 310. Running____+ Applied: ____ = Total____ inlbs 311. Running____+ Applied: ____ = Total____ inlbs 312. Running____+ Applied: ____ = Total____ inlbs 313. Running____+ Applied: ____ = Total____ inlbs 314. Running____+ Applied: ____ = Total____ inlbs 315. Running____+ Applied: ____ = Total____ inlbs 316. Running____+ Applied: ____ = Total____ inlbs 317. Running____+ Applied: ____ = Total____ inlbs 318. Running____+ Applied: ____ = Total____ inlbs 319. Running____+ Applied: ____ = Total____ inlbs 320. Running____+ Applied: ____ = Total____ inlbs 321. Running____+ Applied: ____ = Total____ inlbs			

Seq #	Instructions	Date	Tech	Insp
4.1 (cont)	322. Running____+ Applied: ____ = Total____ inlbs 323. Running____+ Applied: ____ = Total____ inlbs 324. Running____+ Applied: ____ = Total____ inlbs 325. Running____+ Applied: ____ = Total____ inlbs 326. Running____+ Applied: ____ = Total____ inlbs 327. Running____+ Applied: ____ = Total____ inlbs			
4.2	Attach Connector Hole Cover Assembly (56) to CAPE Mounting Plate (1) using MS21209F1-20L Heli-Coil Inserts (installed during fabrication) and 8 **NAS1189E3P16B** (37) bolts Running torque should be 2-18 inlbs; Applied torque should be 66 ±7 inlbs 328. Running____+ Applied: ____ = Total____ inlbs 329. Running____+ Applied: ____ = Total____ inlbs 330. Running____+ Applied: ____ = Total____ inlbs 331. Running____+ Applied: ____ = Total____ inlbs 332. Running____+ Applied: ____ = Total____ inlbs 333. Running____+ Applied: ____ = Total____ inlbs 334. Running____+ Applied: ____ = Total____ inlbs 335. Running____+ Applied: ____ = Total____ inlbs			

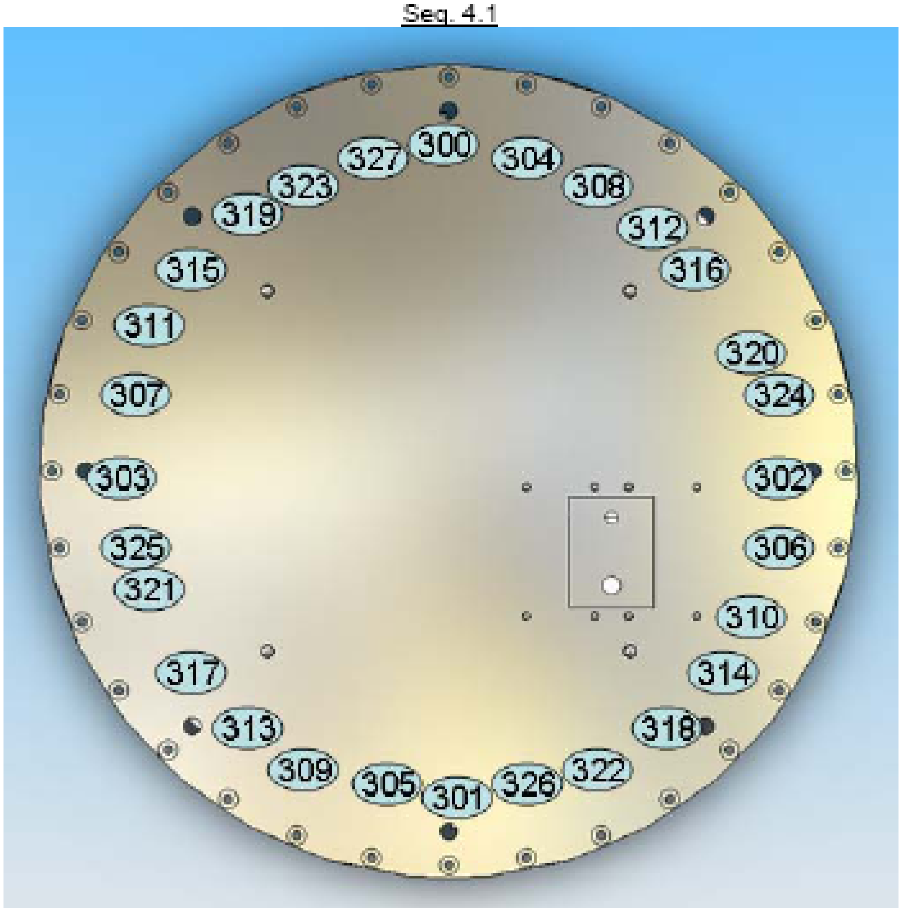
All of the following parts are used in this assembly procedure:

Table 1: Wave #3 Parts

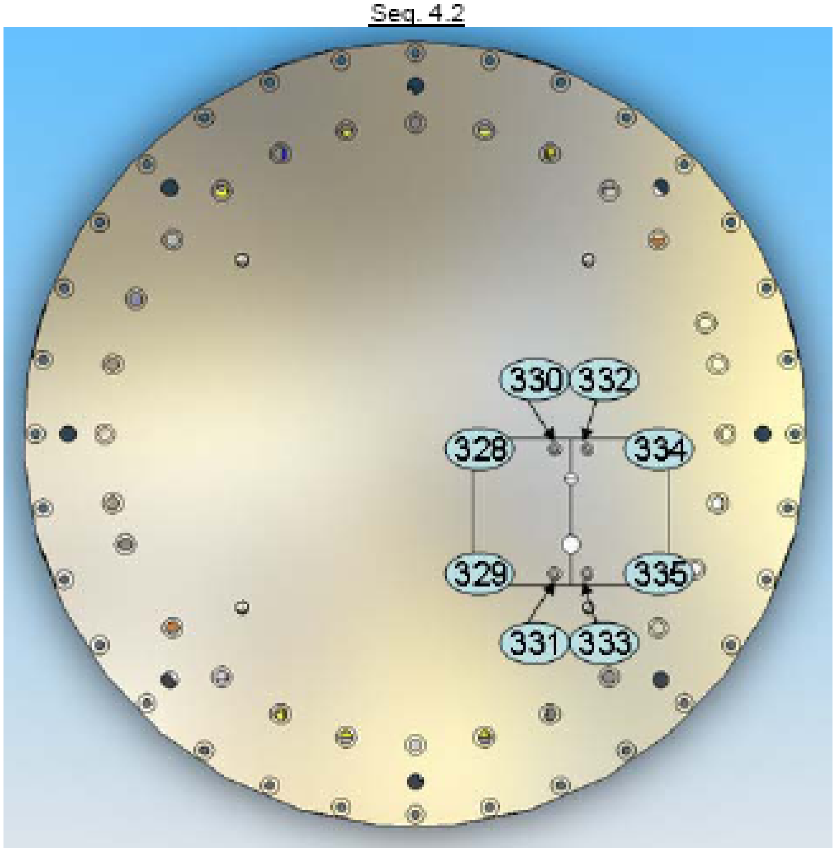
Item Number (per RD-6)	Quantity	Part Name (description)	Part Number	Serial or Lot Number
n/a	1	RIGEX-2 Sub-assembly	RIGEX-WAVE2	
1	1	CAPE Mounting Plate	RIGEX-2006-	
2	1	Experiment Top Plate	RIGEX-2006-	
37	8	bolt	NAS1189E3PB	
54	6	Shroud Seam Bracket		
55	1	Shroud	RIGEX-2006-	
56	1	Connector Hole Cover Assembly	RIGEX-2006-	
57	64	shroud bolt	NAS8402-7	
58	28	bolt	NAS1351N6-20	
59	24	Angled Washer		

The following pictures may be used to help clarify the above assembly procedures. Each picture number corresponds to a particular step in the assembly procedure.

Seq. 4.1



Seq. 4.2



RP-1B

Appendix D: RIGEX Vibration Test Plan

The following document outlines the test plan for Vibration Testing of the RIGEX/CAPE structure at JSC in Houston, TX. This document was prepared by the engineers at STP with input given by the RIGEX team.

Rigidizable Inflatable Get-Away Special Experiment Vibration Test Plan

Document No: RGX20079002

DoD Shuttle/ISS Human Spaceflight Payloads

MEI TECHNOLOGIES
Merging Excellence and Innovation
2525 Bay Area Blvd Suite 300
Houston, TX 77058

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Date: 1 May 2007

Revision: Rev IR

DoD Space Test Program
2101 NASA Parkway JSC-ZR
Houston, TX 77058

Rigidizable Inflatable Get-Away Special Experiment Vibration Test Plan

Revision: IR

Prepared by:	Carson Taylor RIGEX Payload Integration Engineer	Date:

Reviewed by:	Scott Ritterhouse RIGEX Payload Integration Engineer	Date:

Reviewed by:	Darren Bromwell STP Lead Safety Engineer	Date:

Approved by:	Matthew Budde, Major, USAF DoD Human Spaceflight Payload Manager DoD Space Test Program	Date:

Change Record

Rev.	Date	Originator	Approvals	Description
NC	4/26/2007	C. Taylor		Draft
IR				

Table of Contents

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1. INTRODUCTION

1.1 Purpose

The scope of this document is to provide a test plan for random vibration testing of the Rigizable Inflatable Get-Away Special Experiment (RIGEX) payload, which consists of the RIGEX Assembly mounted inside of the Canister for All Payload Ejections (CAPE) Assembly.

The main objective of the test plan is to perform a vibration test to qualify the CAPE-RIGEX Assembly for flight in the Orbiter payload bay on STS-123, where it will be mounted in Bay 13 on the starboard side via a Small Payloads Accommodation (SPA) Beam.

Dynamic environment tests will be conducted with the CAPE-RIGEX Assembly, mounted on a rigid surface to simulate the interface with the SPA Beam in the Shuttle cargo bay. No structural issues or concerns have been identified.

1.2 Points of Contact

The RIGEX information is provided in Table 1.

Table 1: Space Test Program (STP) Points of Contact

Position	Name	Organization	Phone E-mail
RIGEX Cargo Bay Lead PIE	Scott Ritterhouse	MEI	(281) 483 3529 Scott.d.Ritterhouse@nasa.gov
RIGEX Back up PIE	Carson Taylor	OSS	(281) 483 3491 Carson.a.Taylor@nasa.gov
RIGEX Safety Engineer	Theresa Shaffer	MEI	(281) 483 8669 theresa.m.shaffer@nasa.gov
RIGEX DoD Payload Mgr	Matthew Budde, Major, USAF	STP	(281) 483-0361 matthew.j.budde@nasa.gov

1.3 Compliance Documents

- NSTS 37329, Rev. B, *Structural Integration Analyses Responsibility Definition for Space Shuttle Vehicle and Cargo Element Developers*
- CAPE-FCP-0002 *CAPE/RIGEX Fracture Control Plan*
- CAPE-MSVP-0001 *CAPE/ICU Mechanical Systems Verification Plan*

2. PAYLOAD DESCRIPTION

2.1 CAPE-RIGEX Assembly Description

The CAPE-RIGEX Assembly is attached to a SPA (Small Payload Accommodations) Beam on the Orbiter Sidewall, in Bay 13 starboard for STS-123. The CAPE Assembly includes an outer Canister that acts as the interface between the Orbiter Sidewall and RIGEX. The RIGEX Assembly is bolted to the upper flange of the CAPE Canister with 32X ¼-28 bolts, and is not an ejectible payload.

The CAPE Canister has a twenty-two (22) inch inner diameter and is 54 inches long. It is closed at the bottom end by an End Cap bolted to the integrated flange on the cylinder. The RIGEX 'CAPE Mounting Plate' also acts as the lid at the upper end of the Canister and the rest of the RIGEX structure is cantilevered from this Plate inside.

The Mounting Plate of the CAPE Assembly will interface with the SPA Beam utilizing the bolt pattern on the SPA Beam.

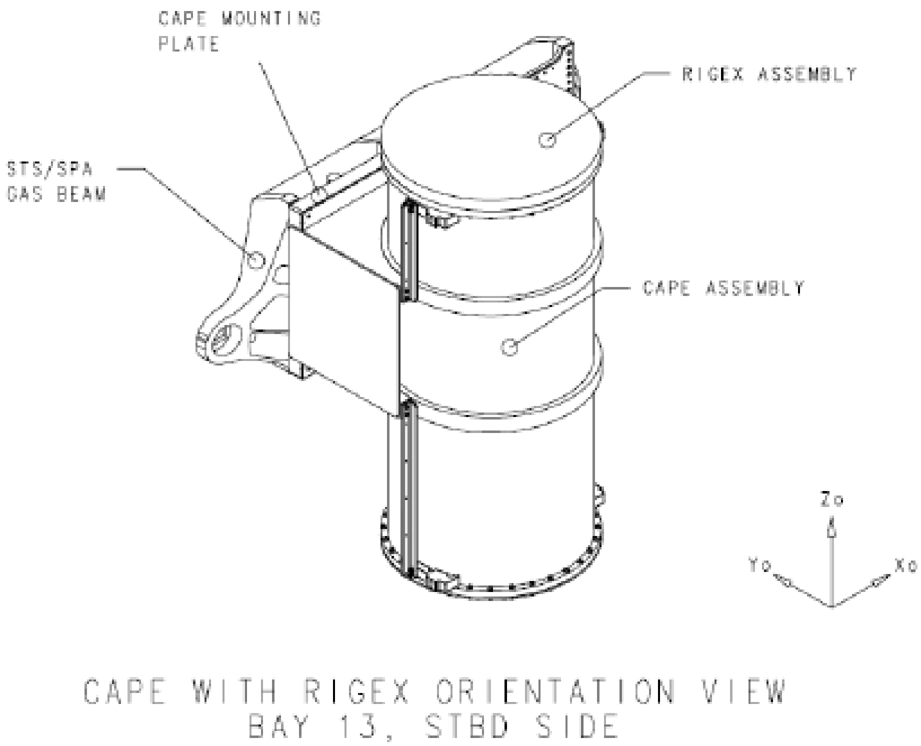


Figure 1: CAPE-RIGEX Assembly Mounted to Bay 13 SPA Beam (Figure by Boeing)

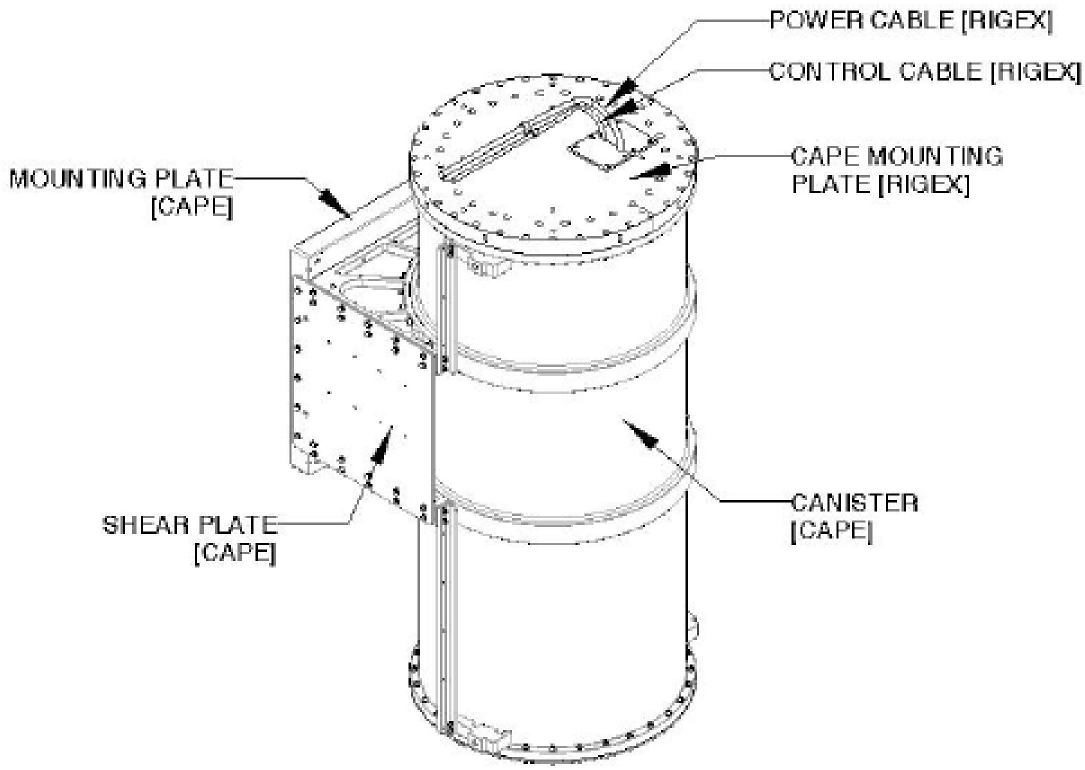


Figure 2: CAPE-RIGEX Assembly

2.2 RIGEX Assembly Description

RIGEX is a Cargo Bay Payload experiment exploring the use of inflatable and rigidizable structures for use on operational space systems. RIGEX is being developed by graduate students at the Air Force Institute of Technology (AFIT).

The Orbiter crew will initiate the experiment and one tube at a time will heat, inflate, cool/rigidize, and vent. Data and pictures will be collected internally by RIGEX. Mechanical properties of the rigidized structure will be assessed by exciting each tube using a piezoelectric patch on the cantilevered end to obtain modal characterization data.

The RIGEX primary structure consists of a top and bottom plate and four vertical outside compartments surrounding an inner compartment as shown in Figure 3. All primary structure consists of 6061-T6 aluminum alloy, and is assembled using NAS fasteners with locking features such as locking helicoils, patchlock bolts, or locking nuts. Three of the outer compartments will house an individual tube/oven assembly and the fourth outer compartment will house the avionics. The nitrogen gas storage cylinders will be housed in the inner compartment.

In order to protect RIGEX during ground processing and protect the inner coating of the CAPE canister, a 0.075" 6061-T6 aluminum shroud is being added that will enclose the outer diameter of RIGEX experiment from the top plate to the bottom plate. Soft bumpers of Delrin will be attached to the bottom

plate of the RIGEX experiment in order to protect the CAPE inner coatings during ground processing. Ground Support Equipment (GSE) handles are mounted to the CAPE Mounting Plate and the Oven Mounting Plate for ground operations and to provide a stable footing for RIGEX ground operations outside of the CAPE. Handles will be removed for flight.

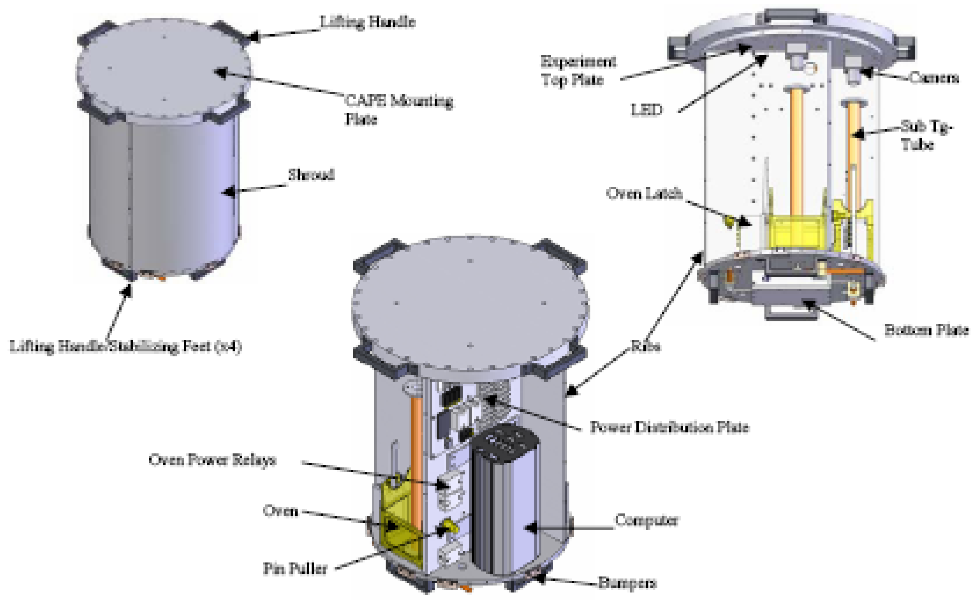


Figure 3: RIGEX Assembly (cables not shown)

2.3 Differences Between the Flight Article and Test Article

The test article will consist of all flight hardware with the following exceptions:

1) Pigtail cables visible in Figure 2 will be GSE test cables rather than the flight cables. Flight cables will be routed along the CAPE Cable Guide and along the Shear Plate mounting fasteners as shown in Figure 4. Each cable will be restrained eight or nine P-clamps for flight. For testing, each of the GSE cables will be restrained with one P-clamp after it emerges from the CAPE Mounting Plate. The remaining cable length will be coiled and restrained nearby using temporary means (i.e. tape) as necessary for vibration testing.

2) The three composite Sub-Tg tubes (labeled in Figure 3) will not be the flight tubes, but will be identical to the flight tubes. These will be replaced with the flight tubes at AFIT following the vibration and EMI testing.

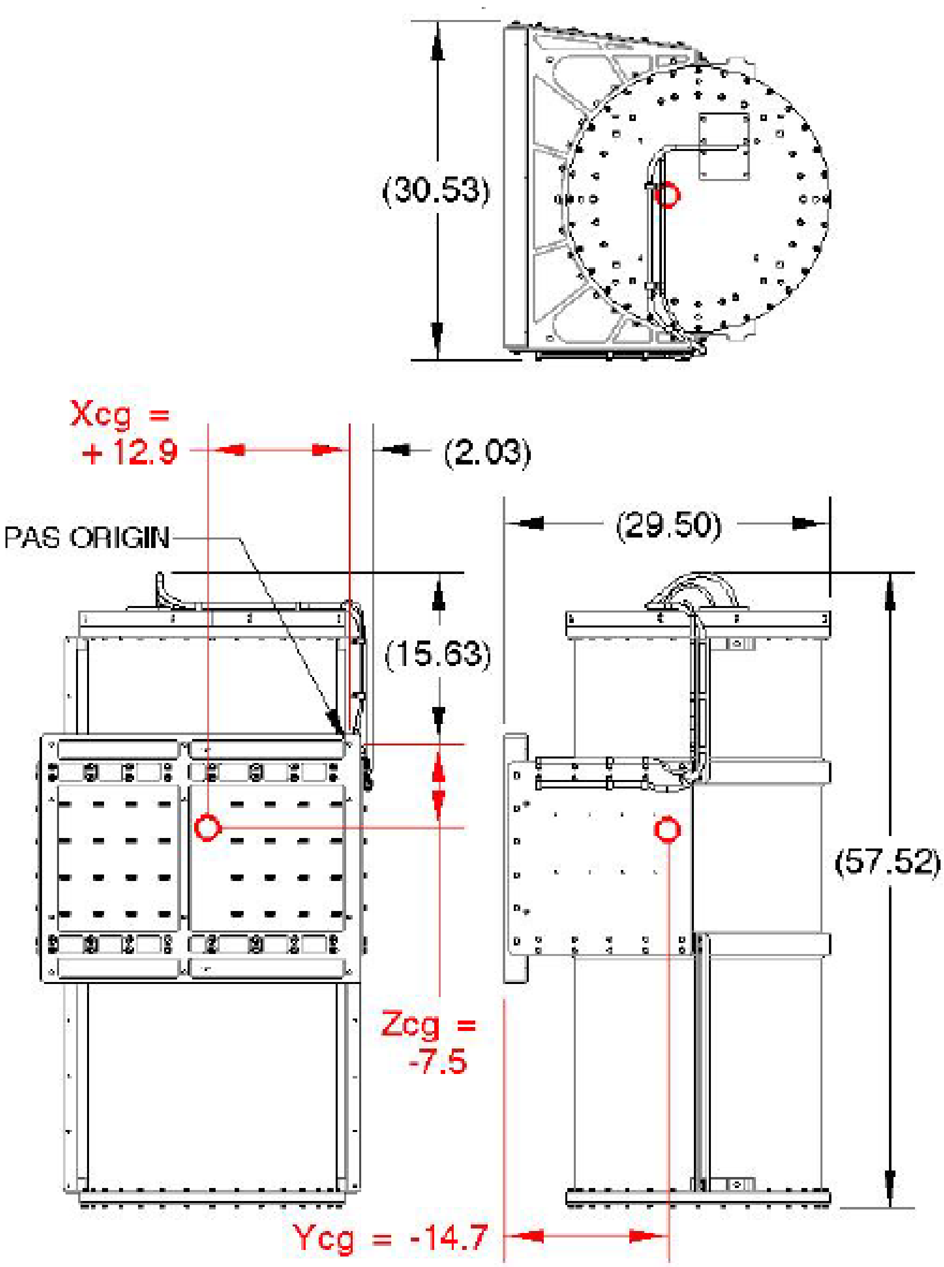


Figure 4: Test Article Dimensions

3. INTEGRATED TEST

3.1 Test Requirements Review

As soon as possible and prior to the test program, Space Test Program (STP) personnel will meet with the facility personnel and review the test requirements, discuss the test flow, and establish the working relationships between STP and the facility personnel.

3.2 Test Readiness Review

Prior to the start of the test, a Test Readiness Review (TRR) will be conducted between STP personnel and the test facility personnel. The purpose of the TRR will be to ensure that the hardware is ready for testing and the facility is ready to conduct the test. Items reviewed at the TRR will include the Test Requirement Document (i.e., the test plan or task preparation sheet), Test Article Hazard Analysis, TRR Summary Sheet (verifies that there are on issues with the test), Drawings as required, and any personnel certifications required.

3.3 Test Fixture

The STP will provide the Vibration Adapter Plate, part number MGSE20075002-301, required to mount the CAPE-RIGEX Assembly to the vibration shaker head during testing. The test facility will provide certified lifting and handling equipment for this plate as required. The Vibration Adapter Plate has many holes with 3/8-24 UNF threads suitable to use as lift points, which weighs approximately 215 lbs. The twelve-hole pattern marked with bubble number 2 in Figure 5 are the holes used for mounting the CAPE-RIGEX Assembly to the Vibration Adapter Plate.

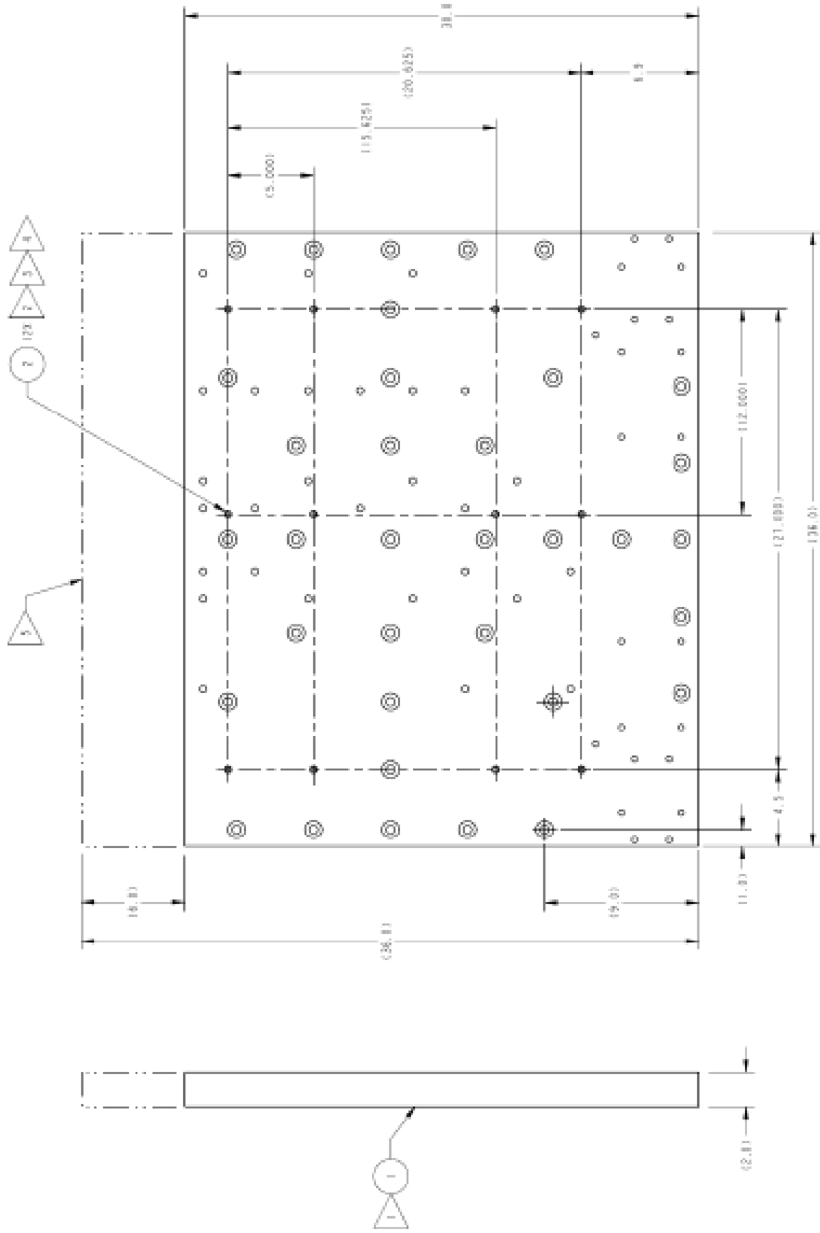


Figure 5: Test Fixture: Vibration Adapter Plate

3.4 Structural Stiffness

The design goal for the CAPE/RIGEX is to have a natural frequency above 35 Hz. The fundamental frequency verification shall be submitted to the JSC Structures Working Group (SWG) and the model verification will be required per NSTS 14046 para 5.1.1.3.2 if the fundamental frequency is below 35 Hz for the sidewall. The CAPE/RIGEX fundamental frequencies are assessed at the payload to GAS Beam interface, which are assumed to be fixed.

If the fundamental frequency is less than 35 hertz for the sidewall and dynamic model verification is required, a test plan will be submitted to the SWG for review and approval at least 60 days prior to the tests. In addition, a detailed model correlation report will also be submitted to the SWG for review and approval. If the first fundamental frequency is below 35 hertz, the design limit load factors in NSTS 21000-IDD-SML, Table 4.0.4.2.4-1can not be used for the CAPE/RIGEX.

3.5 Structural Stiffness Verification (Sine Sweep Test)

The fundamental frequency will be verified by sine sweep testing pre and post vibration testing as allowed by NASA-STD-5002 para 4.2.6.i. The results of this will be compared to the predicted frequencies of the FEM. The sine sweep tests will consists of a series of 0.25 G sweeps in each axis from 10 to 200 Hz (20 to 200 Hz minimum) at maximum rate of 2 oct/min (0.5 oct/min minimum). Preliminary analysis shows that a 0.25 G sine sweep up and down be adequate to determine if the system will react in a linear fashion. However, a real-time assessment will be made as to whether additional sweeps at alternate levels will be conducted if deemed necessary to assess system non-linearities. The test will be conducted in the following manner:

1. Measure and record the torque values of the bolts connecting the test article to the vibration table.
2. Sine Sweep at 0.25 g from 10 to 200 Hz and from 200 to 10 Hz (minimum 20 to 200 Hz) at a maximum rate of 2 oct/min (minimum of 0.5 oct/min).
3. Perform vibration test.
4. Sine Sweep at 0.25 g from 10 to 200 Hz and from 200 to 10 Hz (minimum 20 to 200 Hz) at a maximum rate of 2 oct/min (minimum of 0.5 oct/min).
5. Brief examination of test data.
6. If needed, repeat sweep at higher level to check linearity and repeatability before continuing.
7. Switch to next axis and repeat steps 1-6.
8. Switch to next axis and repeat steps 1-6.

3.6 Random Vibration

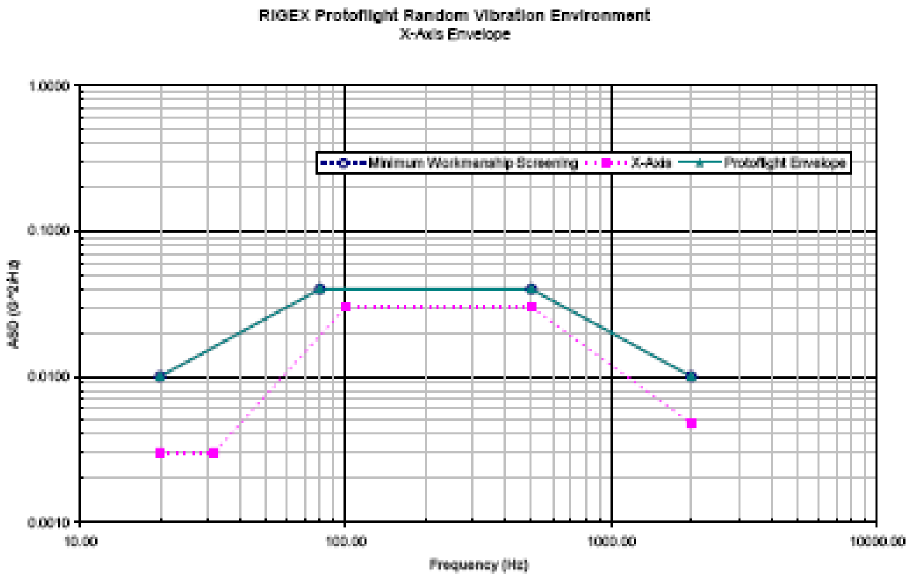
3.6.1 Random Vibration Environment

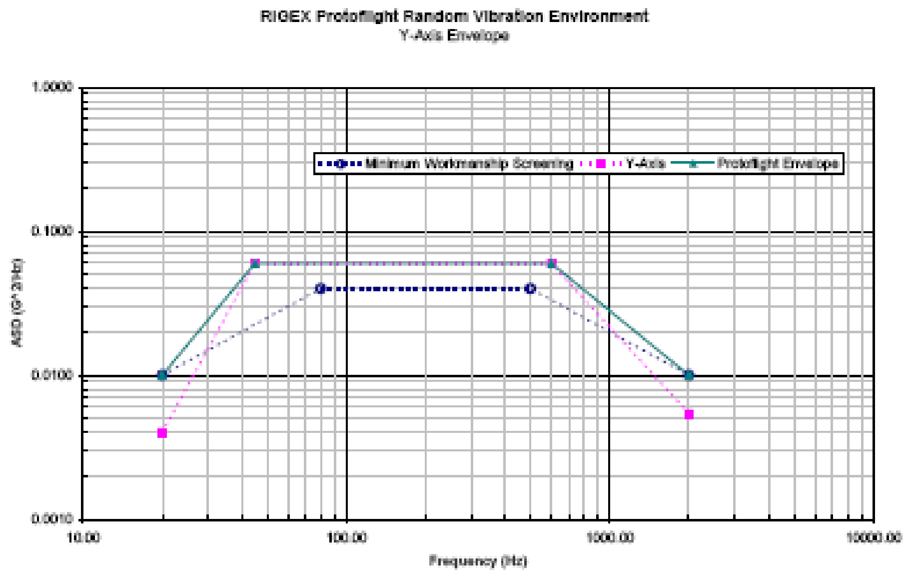
The maximum expected flight level (MEFL) for CAPE/RIGEX is developed using the random vibration environment in NSTS 21000-IDD-SML Table 4.1.6.2.2-1 for all three axes. The workmanship level is defined in NASA-STD-7001 Table 1, which corresponds to 6.8 Grms. The protoflight vibration test (PVT) level for CAPE/RIGEX will envelope these levels in each axis. All of these levels are tabulated below in Table 2, and derived as shown in Figure 6. It should be noted that the PVT level for CAPE/RIGEX does not add 3 dB to the spectra as NASA-STD-7001 states since JSC does not require it to be added.

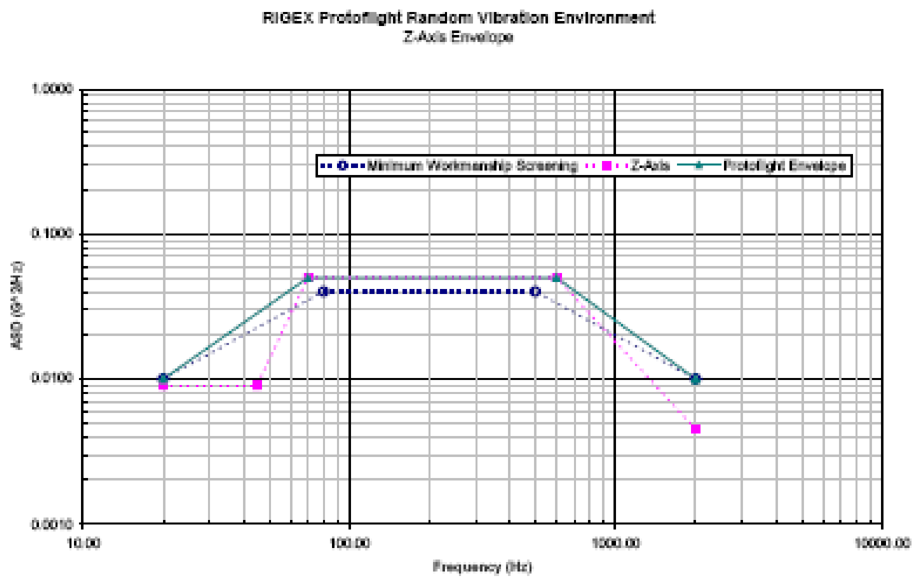
Table 2: Random Vibration Test Levels

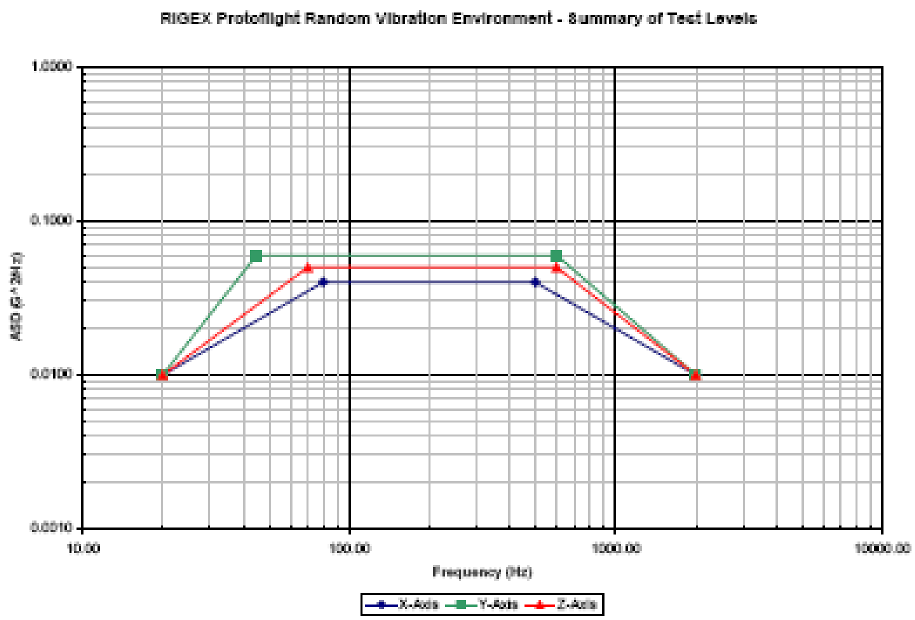
X-Axis	
FREQ (Hz)	ASD (G^2/Hz)
20.00	0.010000
80.00	0.040000
500.00	0.040000
2000.00	0.010000
Y-Axis	
FREQ (Hz)	ASD (G^2/Hz)
20.00	0.010000
45.00	0.060000
600.00	0.060000
2000.00	0.010000
Z-Axis	
FREQ (Hz)	ASD (G^2/Hz)
20.00	0.010000
70.00	0.050000
600.00	0.050000
2000.00	0.010000

Figure 6: Sidewall Random vibration design conditions for CAPE/RIGEX






RIGEX Protoflight Random Vibration Environment
Z-Axis Envelope
Minimum Workmanship Screening
Z-Axis
Protoflight Envelope
1.0000
0.1000
0.0100
0.0010
ASD (G^2/Hz)
10.00
100.00
1000.00
10000.00
Frequency (Hz)


RIGEX Protoflight Random Vibration Environment - Summary of Test Levels
1.0000
0.1000
0.0100
0.0010
ASD (G^2/Hz)
10.00
100.00
1000.00
10000.00
Frequency (Hz)
X-Axis
Y-Axis
Z-Axis

3.6.2 Random Vibration Environment Verification

The CAPE-RIGEX Assembly will be tested to the protoflight levels as shown in Table 2 and Figure 6, in each axis for 60 seconds in accordance with NASA-STD-7001 Para 4.2.1. The CAPE-RIGEX Assembly will be in flight configuration with the exceptions as listed in Section 2.3 of this document.

Sine sweep testing will be done before and after each random vibration test to verify no damage has occurred per section 3.5 of this document.

The Vibration test for each axis shall start at -12dB and increase in 3dB increments until 0 dB is reached.

3.6.3 Force Limit

Force limiting is not required or planned.

3.7 Roles and Responsibilities

3.7.1 Hardware Provider

The hardware provider will designate a test director and associate test director. The test director and associate test director shall have the authority to make changes to the test procedure during the test.

3.7.2 JSC Test Facility Personnel

The test facility will provide all calibrated tools required for the test and any technician required to conduct the test. Quality Engineer and Quality Assurance personnel will be provided by the test facility for the Space Test Program as required. All riggers for moving the hardware will be provided by the test facility.

3.8 Description of Test Set Up

3.8.1 Test Set Up

The test set up is shown in Figure 7.

3.8.2 Instrumentation Locations

The CAPE-RIGEX Assembly test article will be instrumented with a series of tri-axial and single axis accelerometers. A total of over 20 channels will be available for recording data during the testing. Control accelerometer data channels are included as part of the available channels. The accelerometer locations were chosen using engineering judgment; these locations are shown in Figure 7 and described in Table 3. The accelerometers shown as red circles are tri-axial accelerometers and those shown as blue triangles are single axis accelerometers.

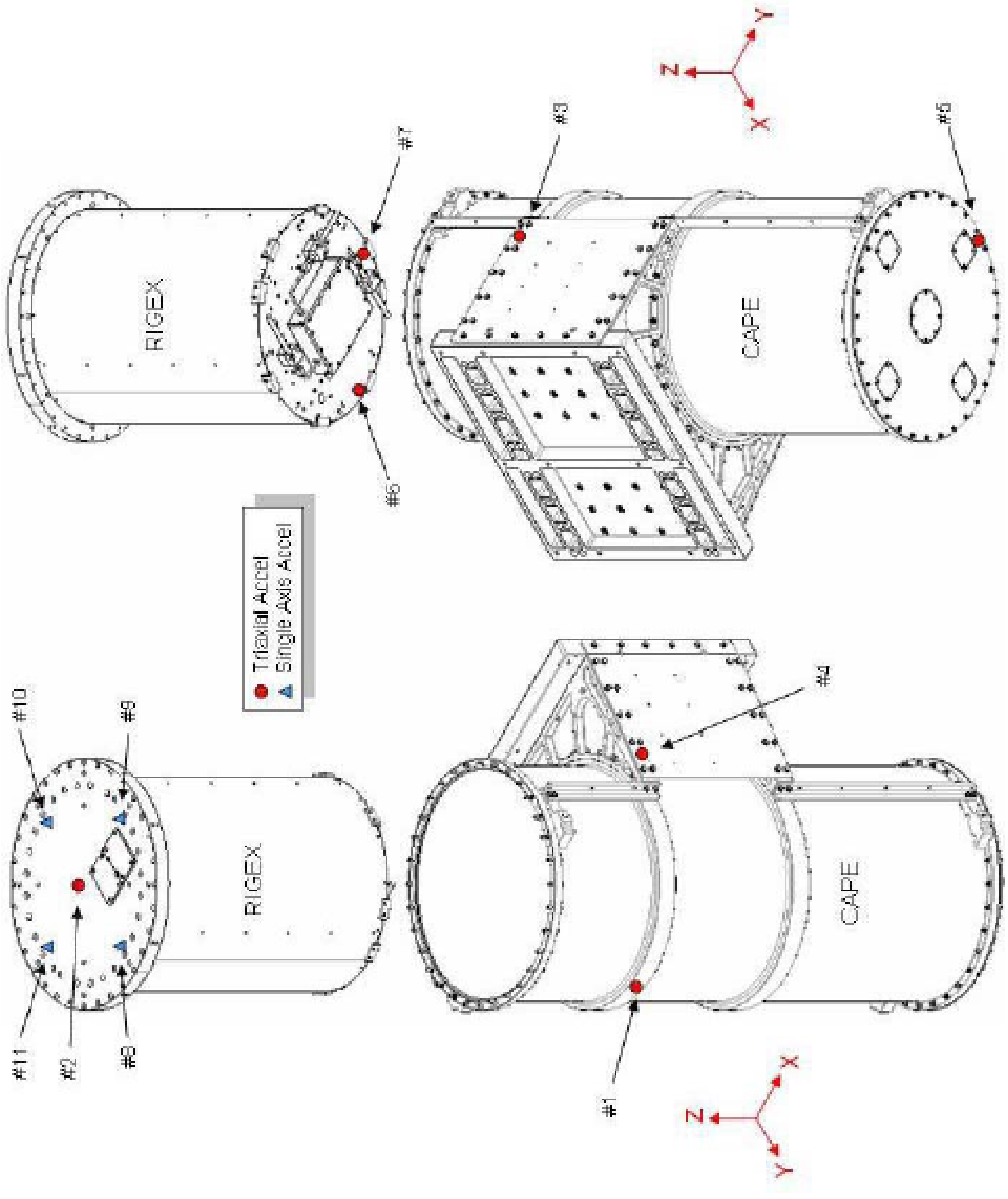


Figure 7: Instrumentation Locations

Table 3: Accelerometer Locations

Channel	Type	Locations	Direction
1	Tri-Axial	Shown as #1 in Figure 7. CAPE Canister, first rib down from the CAPE Lid	X
2	Tri-Axial	Shown as #1 in Figure 7. CAPE Canister, first rib down from the CAPE Lid	Y
3	Tri-Axial	Shown as #1 in Figure 7. CAPE Canister, first rib down from the CAPE Lid	Z
4	Tri-Axial	Shown as #2 in Figure 7. Mounted as close as possible to the center of the CAPE Lid	X
5	Tri-Axial	Shown as #2 in Figure 7. Mounted as close as possible to the center of the CAPE Lid	Y
6	Tri-Axial	Shown as #2 in Figure 7. Mounted as close as possible to the center of the CAPE Lid	Z
7	Tri-Axial	Shown as #3 in Figure 7. Right Shear Plate, corner near Upper Cable Guide	X
8	Tri-Axial	Shown as #3 in Figure 7. Right Shear Plate, corner near Upper Cable Guide	Y
9	Tri-Axial	Shown as #3 in Figure 7. Right Shear Plate, corner near Upper Cable Guide	Z
10	Tri-Axial	Shown as #4 in Figure 7. Left Shear Plate, corner near Upper Cable Guide	X
11	Tri-Axial	Shown as #4 in Figure 7. Left Shear Plate, corner near Upper Cable Guide	Y
12	Tri-Axial	Shown as #4 in Figure 7. Left Shear Plate, corner near Upper Cable Guide	Z
13	Tri-Axial	Shown as #5 in Figure 7. CAPE Endcap (at bottom), 180 deg from Mounting Plate	X
14	Tri-Axial	Shown as #5 in Figure 7. CAPE Endcap (at bottom), 180 deg from Mounting Plate	Y
15	Tri-Axial	Shown as #5 in Figure 7. CAPE Endcap (at bottom), 180 deg from Mounting Plate	Z
16	Tri-Axial	Shown as #6 in Figure 7. RIGEX bottom surface, under computer bay (toward CAPE Left Shear Plate)	X
17	Tri-Axial	Shown as #6 in Figure 7. RIGEX bottom surface, under computer bay (toward CAPE Left Shear Plate)	Y
18	Tri-Axial	Shown as #6 in Figure 7. RIGEX bottom surface, under computer bay (toward CAPE Left Shear Plate)	Z
19	Tri-Axial	Shown as #7 in Figure 7. RIGEX bottom surface, same orientation as #5 on CAPE	X
20	Tri-Axial	Shown as #7 in Figure 7. RIGEX bottom surface, same orientation as #5 on CAPE	Y
21	Tri-Axial	Shown as #7 in Figure 7. RIGEX bottom surface, same orientation as #5 on CAPE	Z
22	Single Axis	Shown as #8 in Figure 7. Mounted on CAPE Lid, along bolt circle to RIGEX Top Plate, at 180 deg from Mounting Plate	Z
23	Single Axis	Shown as #9 in Figure 7. Mounted on CAPE Lid, along bolt circle to RIGEX Top Plate, at 90 deg from Mounting Plate (toward Left Shear Plate)	Z
24	Single Axis	Shown as #10 in Figure 7. Mounted on CAPE Lid, along bolt circle to RIGEX Top Plate, at 0 deg (toward Mounting Plate)	Z
25	Single Axis	Shown as #11 in Figure 7. Mounted on CAPE Lid, along bolt circle to RIGEX Top Plate, at 270 deg (toward Right Shear Plate)	Z

3.8.3 Excitation Method, Levels, and Application Points

Sine Sweeps will be measured by accelerometers at several locations on the CAPE-RIGEX Assembly hardware which will determine the natural frequencies of the structure.

3.9 Boundary Conditions

3.9.1 Support Structure

The test article does not have any support structure. Therefore, there is no support structure that can participate in the test frequency range.

3.9.2 "Free-Free" Test

Not Applicable. The test set up does not require a suspension system.

3.10 Test Reports

The test facility will prepare a test report detailing all test data collected in their standard format for flight hardware. Typically the test report is completed within ten working days after the test has been completed. This test report will include all data collected from the accelerometers, phase angle data associated with the instrumentation, control accelerometer data, and any anomalies encountered during the testing. The test report will also include any pictures that were taken of the test article and the test set up.

4. LINEARITY

Any significant non-linearities will be identified where the data collected allows.

5. TEST SPECIMEN MATH MODEL

A finite element model (FEM) of the CAPE-RIGEX Assembly is constructed and used to predict natural frequencies and mode shapes of the overall system. The CAPE-RIGEX Assembly FEM is shown in Figure 8.

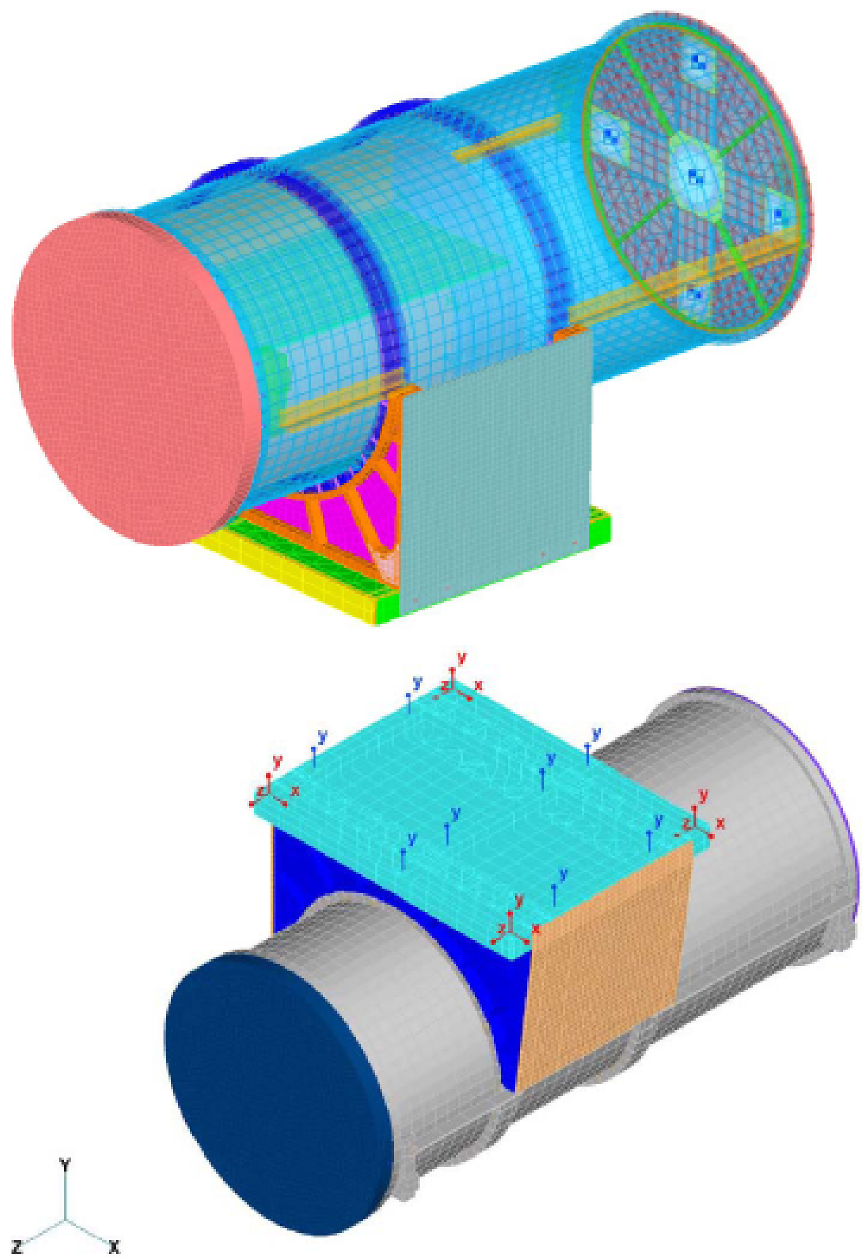


Figure 8: Finite Element Model of CAPE RIGEX (2 views)

6. PRETEST ANALYSIS AND RESULTS

Table 4 and Figure 9 show the preliminary modal analysis of the CAPE-RIGEX system. Analysis indicates one frequency below 35 Hz – at 30.22 Hz – but the mass fraction associated with this mode is only 2%, and therefore it may be considered not significant. The first two dominant modes are are at 55.3 Hz – although this also has a fairly low mass fraction of 6% -- and 68.2 Hz.

Table 4: CAPE-RIGEX: Natural Frequencies with Mass Fraction

MODAL EFFECTIVE MASS FRACTION							
MODE NO.	FREQUENCY Hz	T1		T2		T3	
		FRACTION	SUM	FRACTION	SUM	FRACTION	SUM
1	30.22	0.00	0.00	0.02	0.02	0.00	0.00
2	55.31	0.06	0.06	0.00	0.02	0.01	0.01
3	68.16	0.27	0.33	0.00	0.02	0.01	0.02
4	83.54	0.34	0.67	0.00	0.02	0.00	0.02
5	97.06	0.00	0.67	0.01	0.02	0.49	0.51
6	102.75	0.00	0.67	0.40	0.43	0.00	0.51
7	123.26	0.00	0.68	0.00	0.43	0.00	0.52
8	146.04	0.00	0.68	0.05	0.48	0.28	0.80
9	152.16	0.01	0.68	0.00	0.48	0.00	0.80
10	166.35	0.00	0.68	0.00	0.48	0.02	0.82

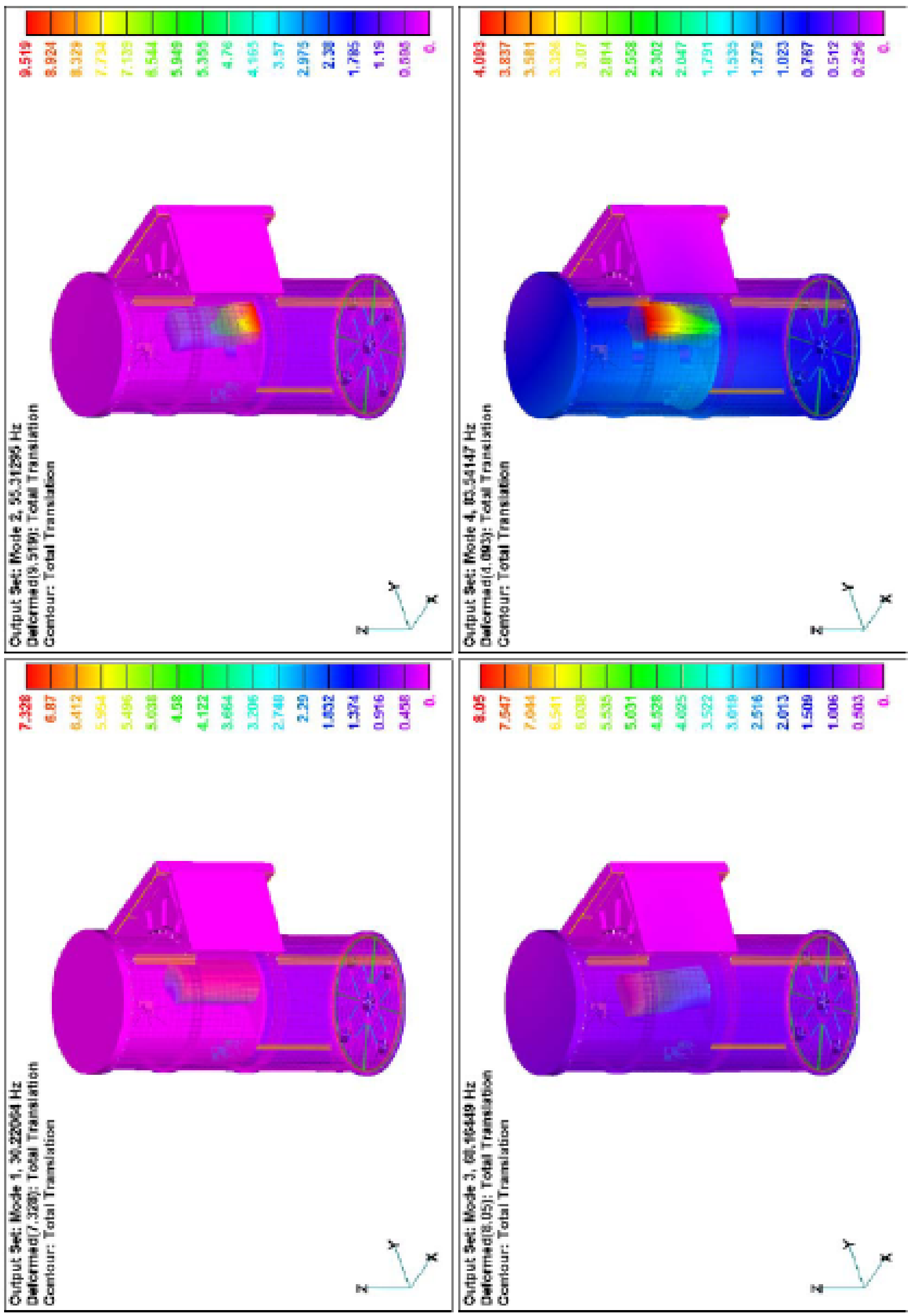


Figure 9: Preliminary Modal Analysis of the CAPE-RIGEX Assembly

7. CORRELATION ANALYSIS

Update FEM model's mass, CG, stiffness to reflect test article and test results.

ACRONYMS

AFIT	Air Force Institute of Technology
CAPE	Canister for All Payload Ejections
CG	Center of Gravity
DoD	Department of Defense
FEM	Finite Element Model
GSE	Ground Support Equipment
JSC	Johnson Space Center
NASA	National Aeronautics and Space Administration
PIE	Payload Integration Engineer
RIGEX	Rigidizable Inflatable Get Away Special Experiment
SPA	Small Payload Accommodation
STP	Space Test Program
SWG	Structures Working Group
TRR	Test Readiness Review
USAF	United States Air Force

Appendix E: OSS Fastener Structural Analysis

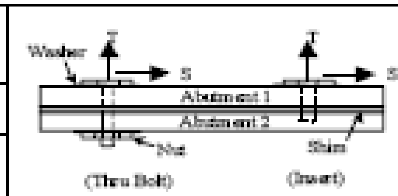
The following document was produced by STP structural analysts. Highlighted in this document are the entries which display the negative margins on the experiment top plate fasteners. This data was produced using STP's mature finite element model software. This document displays the preliminary results of the failed bolted joint between the experimental top plate and the ribs.

OCEANEERING SPACE SYSTEMS	Fastener Structural Analysis		Prepared by:	S. Jonson
	Project:	CAPE/RIGEX	PRELIMINARY RESULTS	
	Interface:	TOP PLATE / RIB PLATE I/F		

General Information			
Flange 1	TOP PLATE		
Part No.	STPH200000000-301		
Flange 2	RIB PLATE		
Part No.	STPH200000000-301		
Part Name	Flat Head Screw		
Part No.	NAS1189-3		
Assembly Item No.		Quantity	24

Joint Checklist

Select Joint Type	◯ Bolt ◉ Insert
Check for Shim	☐
Check for Washer	☐ Top ☐ Base



Load Environment			
Flight Regime	◯ Room Temp ◉ On-Orbit		
Delta Temperature	Hot	95	°F
	Cold	-145	°F

Applied Loads		T	S
Load Type(s)	☑ Nominal	841	126
	☐ Failsafe		

Safety Factors	◯ Test ◉ No Test
Safety Factor, Ultimate	2.00
Safety Factor, Yield	1.25
Safety Factor, Failsafe	n/a
Safety Factor, Gapping	1.20
Fitting Factor, Tension	1.15
Fitting Factor, Shear	1.15
Torque Uncertainty Factor	0.25
Nut Factor	0.10

Torque		
Maximum	35	in-lbs
Minimum	31	in-lbs

Mechanical Preload		
Maximum	2328	lbs
Minimum	1120	lbs

Thermal Preload			
Preload	Hot	168	lbs
	Cold	-245	lbs

Material Properties

Joint Component	Material*	F_{tu} (psi)	F_{ty} (psi)	F_{su} (psi)	E (psi)	α_{hot} (in/in/°F)	α_{cold} (in/in/°F)	TDF
Fastener	A286, 180 ksi	180000	150000	117000	2.85E+07	9.10E-06	8.55E-06	0.97
Abutment 1	Al Aly 6061-T6	42000	35000	28000	9.90E+06	1.29E-05	1.22E-05	0.94
Abutment 2	Al Aly 6061-T6	42000	35000	28000	9.90E+06	1.29E-05	1.22E-05	0.94
Nut	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Shim	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Washer	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Insert (parent material)	Al Aly 6061-T6	42000	35000	28000	9.90E+06	1.29E-05	1.22E-05	0.94

Thread Type		
10-32 UNJF-3A	◉ Lubricated threads ◯ Non-lubricated threads	
Nominal Diameter, D	0.190	in
Minor Diameter, D_m	0.150	in
Threads Per Inch, n	32	1/in
Max Minor Dia of Int Thread, K_{nmax}	0.168	in
Min Pitch Dia of Ext Thread, E_{smin}	0.167	in
Min Major Dia of Ext Thread, D_{smin}	0.184	in
Max Pitch Dia of Int Thread, E_{nmax}	0.173	in

Joint Input Data		
Abutment 1 Thickness, t_1	0.625	in
Abutment 2 Thickness, t_2	0.380	in
Shim Thickness, t_{shim}	0.000	in
Washer Thickness, tw_1	0.000	in
Washer Thickness, tw_2	0.000	in
Fastener Head Diameter, D_{head}	0.303	in
Washer Diameter, D_w	0.000	in
Nut Head Diameter, D_{nut}		in
Hole diameter, d_{hole}	0.201	in
Grip, Threaded Portion, l_t	0.380	in
Grip, Unthreaded portion, l_s	0.625	in

Insert Input Data (if applicable)		
Number of Loaded Coils	10.160	2
Nominal Length, Q	0.380	in
Thread Type	◉ Locking ◯ Free-Running	

Nut Input Data (if applicable)		
Tensile Allowable	n/a	lbs

Nut or Insert Part Number	

Assume 180 ksi A286 fasteners and 0.38" Insert Length

OCEANEERING
SPACE SYSTEMS

Fastener Structural Analysis		Prepared by:	S. Jonson
Project:	CAPE/RIGEX	Checked by:	
Interface:	TOP PLATE / RIB PLATE I/F	Date:	

Joint Geometric Parameters

Shank Area, A_{shank}	0.028	in^2	Distance between head and nut, L	1.005	in
Root Area, A_{root}	0.018	in^2	Center Line Thickness, C	0.503	in
Tensile Stress Area, A_{tens}	0.019	in^2	Loading Plane Factor, n=C/L	0.500	
Max Head Diameter (D_w, D_{head}, D_{nut})	0.303	in	Compression Area, A_c	0.438	in^2
Effective Grip Length, l	0.815	in	Joint Modulus of Elasticity, E_j	9.90E+06	psi
Stack Thickness, t_{stack}	1.005	in	Fastener Stiffness Coefficient, C	0.317	

Allowable Loads

Tension (Ult)	4950	lbf (shank)
Tension (Ult)	3391	lbf
Tension (Yld)	2828	lbf
Shear (Ult)	1998	lbf (root)

Fastener Tensile Loads

Limit	841	lbf
Ultimate	2800	lbf
Yield	2695	lbf
Failsafe	n/a	lbf

Thread Shear, Fastener

Engagement	0.148	in
Shear Area, Ext	0.039	in^2
Shear Area, Int	0.061	in^2
J Factor	0.638	
Eff. Engagement	0.148	in
Allowable Load	7795	lbf

Combined Loads

Applied Shear, (Ult)	290	lbf	m = n/a
Applied Shear, (FS)	n/a	lbf	n = n/a
Bending Stress	n/a	psi	
Bending Stress, (FS)	n/a	psi	
Ultimate Bending Stress Ratio, R_{bu}	n/a		
Ultimate Tensile Stress Ratio, R_{tu}	0.826		
Ultimate Shear Stress Ratio, R_{su}	0.145		
Failsafe Bending Stress Ratio, R_{bfs}	n/a		
Failsafe Tensile Stress Ratio, R_{tfs}	n/a		
Failsafe Shear Stress Ratio, R_{sfs}	n/a		

Insert Allowable

Tensile Area, A_{tens}	0.033	in^2
Engagement	0.148	in
Shear Area, Ext	0.066	in^2
Shear Area, Int	0.103	in^2
J Factor	2.729	
Req Engagement	0.404	in
Allowable Load	2246	lbf

Margin of Safety Summary - Fastener

MS =			
MS =	0.21	(Ult)	Root Tension
MS =	0.05	(Yld)	Root Tension
MS =	n/a	(FS)	Root Tension
MS =	1.78	(Ult)	Thread Shear
MS =	n/a	(FS)	Thread Shear
MS =	n/a	(Ult)	Bending
MS =	n/a	(Yld)	Bending
MS =	n/a	(FS)	Bending
MS =	0.46	(Ult)	Combined
MS =	n/a	(FS)	Combined
MS =	+High	(Ult)	Shear
MS =	n/a	(FS)	Shear
MS =	0.03	(Nom)	Gapping

Margin of Safety Summary - Insert

MS =			
MS =	-0.20	(Ult)	Thread Shear, Insert
MS =	n/a	(FS)	Thread Shear, Insert

Margin of Safety Summary - Nut

MS =			
MS =	n/a	(Ult)	Thread Shear, Nut
MS =	n/a	(FS)	Thread Shear, Nut

Notes: +High represents margins of safety greater than 2.0

OCEANEERING SPACE SYSTEMS

CAPE/RIGEX
STRESS ANALYSIS SUMMARY

This analysis is for Nominal _X_ Failsafe _____ Configuration(s)

Flange 1	TOP PLATE	P/N	STPH200000000-301
Flange 2	RIB PLATE	P/N	STPH200000000-301
Part Name	Flat Head Screw	P/N	NAS1189-3

Material A286, 180 ksi Analysis Temperature -75 to 165 °F

Fitting Factor ____ No _X_ Yes (Factor = 1.15 Tension 1.15 Shear)

Safety Factor ____ No _X_ Yes (Factor = 2.00 Ult 1.25 Yld n/a FS)

Ref No.	Location Checked	Failure Mode	Load Case	Load Type	Member Stress/Load		Material Strength		Margin of Safety
1	Root	Tension	On-Orbit	Ultimate	2800	lbf	3391	lbf	0.21
2	Root	Tension	On-Orbit	Yield	2685	lbf	2826	lbf	0.05
3	Root	Tension	On-Orbit	Failsafe	n/a	lbf	n/a	lbf	n/a
4	Thread - Int	Shear	On-Orbit	Ultimate	2800	lbf	7795	lbf	1.78
5	Thread - Int	Shear	On-Orbit	Failsafe	n/a	lbf	n/a	lbf	n/a
6	Bending	Tension	On-Orbit	Ultimate	n/a	psi	n/a	psi	n/a
7	Bending	Tension	On-Orbit	Yield	n/a	psi	n/a	psi	n/a
8	Bending	Tension	On-Orbit	Failsafe	n/a	psi	n/a	psi	n/a
9	Root	Tension Shear	On-Orbit	Ultimate	2800 290	lbf lbf	3391 1998	lbf lbf	0.46
10	Root	Tension Shear	On-Orbit	Failsafe	n/a n/a	lbf lbf	n/a n/a	lbf lbf	n/a
11	Root	Shear	On-Orbit	Ultimate	290	lbf	1998	lbf	+High
12	Root	Shear	On-Orbit	Failsafe	n/a	lbf	n/a	lbf	n/a
13	Joint	Gapping	On-Orbit	Limit	849	lbf	1120	lbf	0.03
14	Thread - Ext	Shear	On-Orbit	Ultimate	2800	lbf	2246	lbf	-0.20
15	Thread - Ext	Shear	On-Orbit	Failsafe	n/a	lbf	n/a	lbf	n/a
16	Nut	Shear	On-Orbit	Ultimate	n/a	lbf	n/a	lbf	n/a
17	Nut	Shear	On-Orbit	Failsafe	n/a	lbf	n/a	lbf	n/a

OCEANEERING SPACE SYSTEMS

Fastener Structural Analysis		Prepared by:	S. Jonson
Project:	CAPE/RIGEX	Checked by:	
Interface:	TOP PLATE / RIB PLATE I/F	Date:	

Joint Geometric Parameters					
Shank Area, A_{shank}	0.028	in^2	Distance between head and nut, L	1.125	in
Root Area, A_{root}	0.018	in^2	Center Line Thickness, C	0.563	in
Tensile Stress Area, A_{tens}	0.019	in^2	Loading Plane Factor, n=C/L	0.500	
Max Head Diameter (D_w, D_{head}, D_{nut})	0.303	in	Compression Area, A_c	0.481	in^2
Effective Grip Length, l	0.875	in	Joint Modulus of Elasticity, E_j	9.90E+06	psi
Stack Thickness, t_{stack}	1.125	in	Fastener Stiffness Coefficient, C	0.208	

Allowable Loads		
Tension (Ult)	4950	lbf (shank)
Tension (Ult)	3391	lbf
Tension (Yld)	2828	lbf
Shear (Ult)	1998	lbf (root)

Fastener Tensile Loads		
Limit	841	lbf
Ultimate	2780	lbf
Yield	2673	lbf
Failsafe	n/a	lbf

Thread Shear, Fastener		
Engagement	0.148	in
Shear Area, Ext	0.039	in^2
Shear Area, Int	0.061	in^2
J Factor	0.638	
Eff. Engagement	0.148	in
Allowable Load	10256	lbf

Combined Loads			
Applied Shear, (Ult)	290	lbf	m = n/a
Applied Shear, (FS)	n/a	lbf	n = n/a
Bending Stress	n/a	psi	
Bending Stress, (FS)	n/a	psi	
Ultimate Bending Stress Ratio, R_{bu}	n/a		
Ultimate Tensile Stress Ratio, R_{tu}	0.820		
Ultimate Shear Stress Ratio, R_{su}	0.145		
Failsafe Bending Stress Ratio, R_{bfs}	n/a		
Failsafe Tensile Stress Ratio, R_{tfs}	n/a		
Failsafe Shear Stress Ratio, R_{sfs}	n/a		

Insert Allowable		
Tensile Area, A_{tens}	0.033	in^2
Engagement	0.148	in
Shear Area, Ext	0.066	in^2
Shear Area, Int	0.103	in^2
J Factor	2.729	
Req Engagement	0.404	in
Allowable Load	2955	lbf

Margin of Safety Summary - Fastener		
MS = 0.22 (Ult)	Root Tension	
MS = 0.06 (Yld)	Root Tension	
MS = n/a (FS)	Root Tension	
MS = +High (Ult)	Thread Shear	
MS = n/a (FS)	Thread Shear	
MS = n/a (Ult)	Bending	
MS = n/a (Yld)	Bending	
MS = n/a (FS)	Bending	
MS = 0.48 (Ult)	Combined	
MS = n/a (FS)	Combined	
MS = +High (Ult)	Shear	
MS = n/a (FS)	Shear	
MS = 0.02 (Nom)	Gapping	

Margin of Safety Summary - Insert	
MS = 0.06 (Ult)	Thread Shear, Insert
MS = n/a (FS)	Thread Shear, Insert

Margin of Safety Summary - Nut	
MS = n/a (Ult)	Thread Shear, Nut
MS = n/a (FS)	Thread Shear, Nut

Notes: +High represents margins of safety greater than 2.0

OCEANEERING SPACE SYSTEMS

CAPE/RIGEX
STRESS ANALYSIS SUMMARY

This analysis is for Nominal _X_ Failsafe _____ Configuration(s)

Flange 1 TOP PLATE P/N STPH200000000-301

Flange 2 RIB PLATE P/N STPH200000000-301

Part Name Flat Head Screw P/N NAS1189-3

Material A286, 180 ksi Analysis Temperature -75 to 165 °F

Fitting Factor ____No _X_Yes (Factor = 1.15 Tension 1.15 Shear)

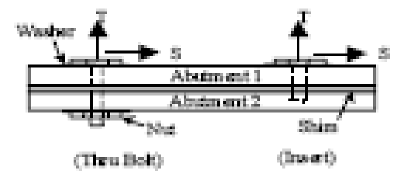
Safety Factor ____No _X_Yes (Factor = 2.00 Ult 1.25 Yld n/a FS)

Ref No.	Location Checked	Failure Mode	Load Case	Load Type	Member Stress/Load		Material Strength		Margin of Safety
1	Root	Tension	On-Orbit	Ultimate	2780	lbf	3391	lbf	0.22
2	Root	Tension	On-Orbit	Yield	2673	lbf	2826	lbf	0.06
3	Root	Tension	On-Orbit	Failsafe	n/a	lbf	n/a	lbf	n/a
4	Thread - Int	Shear	On-Orbit	Ultimate	2780	lbf	10256	lbf	+High
5	Thread - Int	Shear	On-Orbit	Failsafe	n/a	lbf	n/a	lbf	n/a
6	Bending	Tension	On-Orbit	Ultimate	n/a	psi	n/a	psi	n/a
7	Bending	Tension	On-Orbit	Yield	n/a	psi	n/a	psi	n/a
8	Bending	Tension	On-Orbit	Failsafe	n/a	psi	n/a	psi	n/a
9	Root	Tension Shear	On-Orbit	Ultimate	2780 290	lbf lbf	3391 1998	lbf lbf	0.48
10	Root	Tension Shear	On-Orbit	Failsafe	n/a n/a	lbf lbf	n/a n/a	lbf lbf	n/a
11	Root	Shear	On-Orbit	Ultimate	290	lbf	1998	lbf	+High
12	Root	Shear	On-Orbit	Failsafe	n/a	lbf	n/a	lbf	n/a
13	Joint	Gapping	On-Orbit	Limit	860	lbf	1120	lbf	0.02
14	Thread - Ext	Shear	On-Orbit	Ultimate	2780	lbf	2955	lbf	0.06
15	Thread - Ext	Shear	On-Orbit	Failsafe	n/a	lbf	n/a	lbf	n/a
16	Nut	Shear	On-Orbit	Ultimate	n/a	lbf	n/a	lbf	n/a
17	Nut	Shear	On-Orbit	Failsafe	n/a	lbf	n/a	lbf	n/a

Fastener Structural Analysis		Prepared by:	S. Jonson
Project:	CAPE/RIDEX	PRELIMINARY RESULTS	
Interface:	TOP PLATE / RIB PLATE I/F	Date:	

General Information			
Flange 1	TOP PLATE		
Part No.	STPH200000000-301		
Flange 2	RIB PLATE		
Part No.	STPH200000000-301		
Part Name	Flat Head Screw		
Part No.	NAS1189-3		
Assembly Item No.		Quantity	24

Joint Checklist	
Select Joint Type	○ Bolt ◉ Insert
Check for Shim	☐
Check for Washer	☐ Top ☐ Base



Load Environment			
Flight Regime	○ Room Temp ◉ On-Orbit		
Delta Temperature	Hot	95	°F
	Cold	-145	°F

Applied Loads			
Load Type(s)		T	S
	☑ Nominal	841	126
	☐ Failsafe		

Safety Factors	○ Test ◉ No Test
Safety Factor, Ultimate	2.00
Safety Factor, Yield	1.25
Safety Factor, Failsafe	n/a
Safety Factor, Gapping	1.20
Fitting Factor, Tension	1.15
Fitting Factor, Shear	1.15
Torque Uncertainty Factor	0.25
Nut Factor	0.10

Torque		
Maximum	35	in-lbs
Minimum	31	in-lbs

Mechanical Preload		
Maximum	2328	lbs
Minimum	1120	lbs

Thermal Preload			
Preload	Hot	155	lbs
	Cold	-247	lbs

Material Properties								
Joint Component	Material*	F_{tu} (psi)	F_{ty} (psi)	F_{su} (psi)	E (psi)	α_{fast} (in/in/°F)	α_{abut} (in/in/°F)	TDF
Fastener	A286, 160 ksi	160000	150000	117000	2.85E+07	9.10E-06	8.55E-06	0.97
Abutment 1	Al Aly 6061-T6	42000	35000	28000	9.90E+06	1.29E-05	1.22E-05	0.94
Abutment 2	Al Aly 6061-T6	42000	35000	28000	9.90E+06	1.29E-05	1.22E-05	0.94
Nut	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Shim	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Washer	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Insert (parent material)	Al Aly 6061-T6	42000	35000	28000	9.90E+06	1.29E-05	1.22E-05	0.94

Thread Type		
10-32 UNJF-3A	◉ Lubricated threads ○ Non-lubricated threads	
Nominal Diameter, D	0.190	in
Minor Diameter, D_m	0.150	in
Threads Per Inch, n	32	1/in
Max Minor Dia of Int Thread, K_{nmax}	0.168	in
Min Pitch Dia of Ext Thread, E_{smin}	0.167	in
Min Major Dia of Ext Thread, D_{smin}	0.184	in
Max Pitch Dia of Int Thread, E_{nmax}	0.173	in

Joint Input Data		
Abutment 1 Thickness, t_1	0.625	in
Abutment 2 Thickness, t_2	0.500	in
Shim Thickness, t_{shim}	0.000	in
Washer Thickness, tw_1	0.000	in
Washer Thickness, tw_2	0.000	in
Fastener Head Diameter, D_{head}	0.303	in
Washer Diameter, D_w	0.000	in
Nut Head Diameter, D_{nut}		in
Hole diameter, d_{hole}	0.201	in
Grip, Threaded Portion, l_t	0.500	in
Grip, Unthreaded portion, l_s	0.625	in

Insert Input Data (if applicable)		
Number of Loaded Coils	14.000	2.63
Nominal Length, Q	0.500	in
Thread Type	◉ Locking ○ Free-Running	

Nut Input Data (if applicable)		
Tensile Allowable	n/a	lbs

Nut or Insert Part Number	

Modify Length of Insert to Increase Allowable Shear

Assume 160 ksi A286 fasteners
and 0.50" Insert Length

Appendix F: RIGEX Oven Assembly Memorandum

Air Force Institute of Technology
Wright Patterson Air Force Base

MEMORANDUM

FROM: ENS Brady D. O'Neal, USN

SUBJECT: Structural Verification of RIGEX Oven Assembly

1. The design and effectiveness of the three heater boxes (ovens) used on the RIGEX flight prototype are a portion of the science being examined in the RIGEX space experiment. The various components that make up the oven assembly are experimental, and include the following components: oven, Sub-Tg tube, pin-puller, oven latch, oven mounting bracket, and the RIGEX structure. Structural verification of the RIGEX oven assembly is essential to RIGEX's mission success.

2. The design of the oven assembly has been through several iterations since RIGEX's conception. The flight configuration is currently assembled and ready for implementation. This current design stems from the vibroacoustic testing completed by 2ndLt Sarah Helms in 2005 using an MB Dynamics C40HP Electrodynamic Vibration Exciter. 2ndLt Helms used a realistic flight load environment vibration profile determined by NASA in compliance with NSTS-21000-IDD-SML *Shuttle Orbiter/Small Payload Accomodation Interfaces* and NASA-STD-7001 *Payload Vibroacoustic Test Criteria* to test the oven assembly's ability to withstand random vibration. In her experimentation, the oven assembly experienced a maximum of 8.2 grms of random vibration. Tolerances were set in the experiment's control software to avoid over-testing. A general analysis and thorough visual inspection were used to verify the structural integrity of the oven assembly with respect to expected launch loads.

3. This memorandum, in conjunction with previous testing, is meant to provide justification for the design and the materials used in the oven assembly. Thorough structural testing of the oven assembly shows that the use of non-NAS fasteners and Ultem as the oven box material is acceptable.

4. The RIGEX oven assembly has been tested under a realistic flight load vibration environment. The oven assembly withstood the severe testing loads and performed as expected. In summary, the oven assembly is ready for space flight.

BRADY D. O'NEAL, ENS, USN

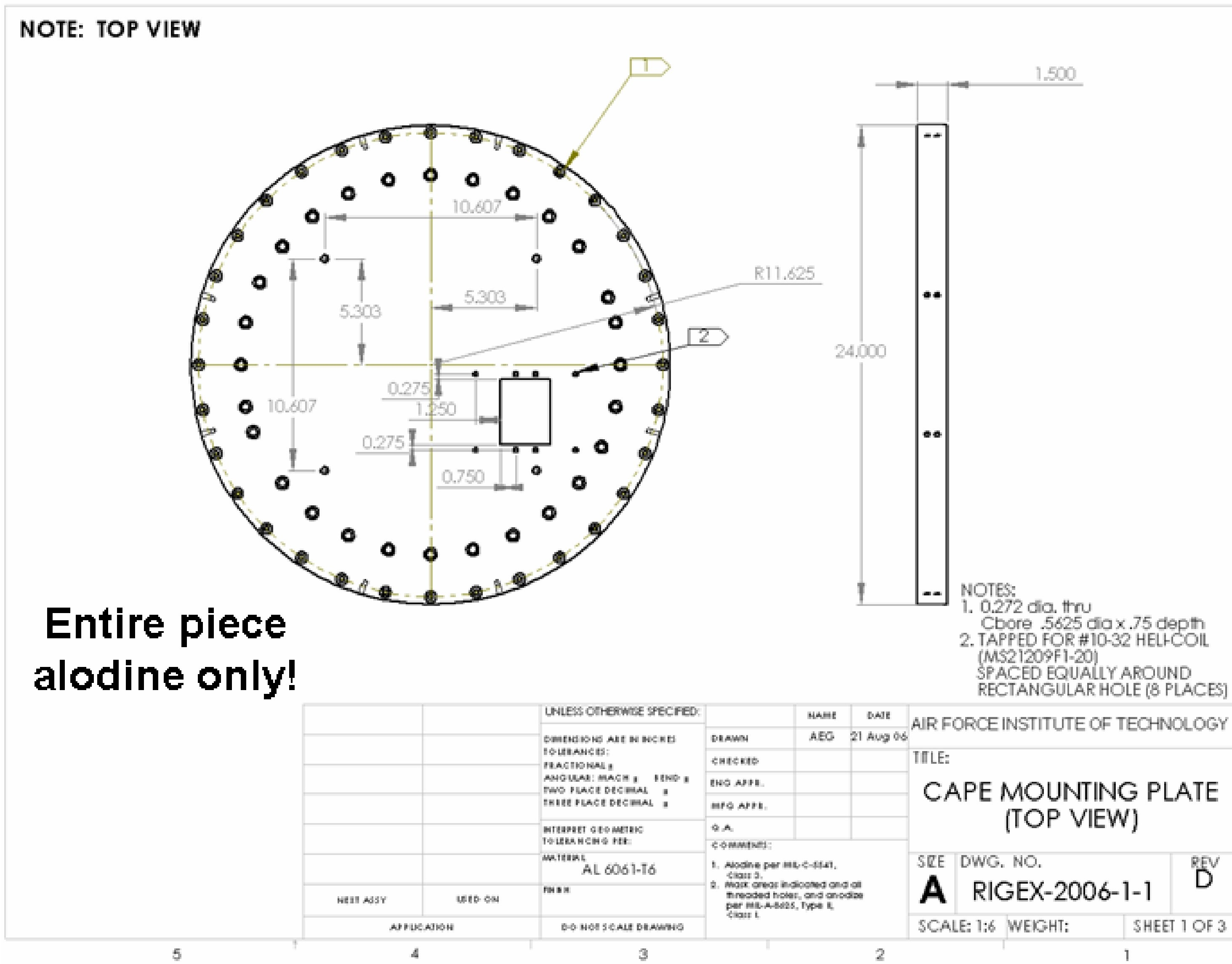
AFIT/ENY

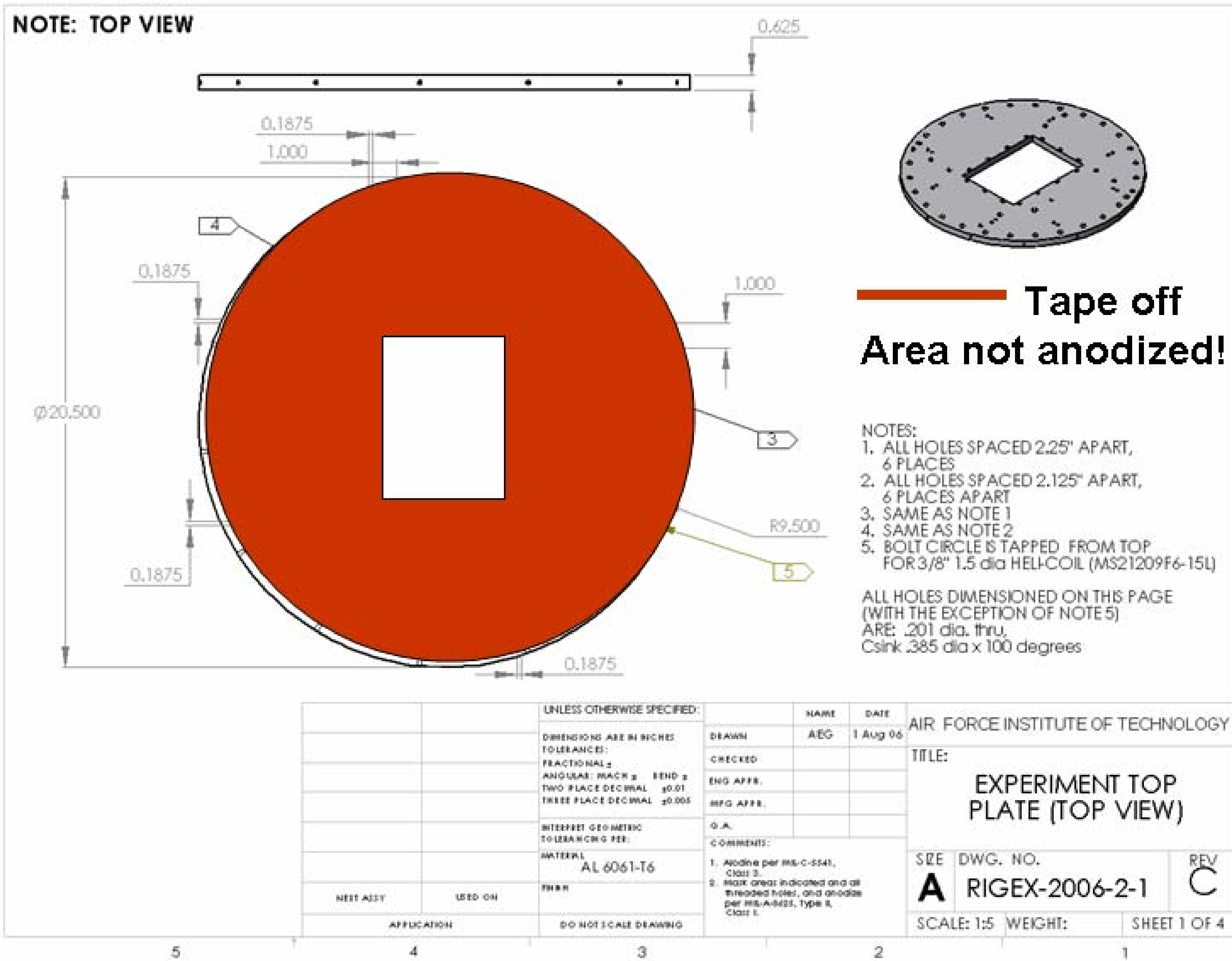
Appendix G: RIGEX Operational and Survivability List

		Operating Limits								Storage Limits*			
		Required Voltage (VDC)		Current (mA)		Temp (°C)		Humidity %		Temp (°C)		Humidity %	
Subsystem	Component	Low	High	Low	High	Low	High	Low	High	Low	High	High	Low
General													
	Master Bond Epoxy	N/A	N/A	N/A	N/A	-270	205			-270	205		
Experiment													
	Sub-Tg Tube	N/A	N/A	N/A	N/A	N/A	110	N/A	N/A	N/A	110	N/A	N/A
	Piezoelectric Actuator - PZT QuickPack strain actuator	-500	1500			N/A	85	N/A	N/A		160	N/A	N/A
	Accelerometer - Precision Aligned wide Input Voltage Triaxial Accel.	2.7	5	0.6	1500	-40	85	N/A	N/A	-55	150	N/A	N/A
	Pin Puller	5	5	17	980	-60	70	N/A	N/A	-60	70	N/A	N/A
Command and Control (Computer)													
	Quartz Timer/Counter	5	5	0	220	-40	85	N/A	N/A	-40	85	N/A	N/A
	PC-104 Computer (imaging / data acq)	5	5		90	-40	85	N/A	N/A	-55	85	N/A	N/A
	Filter - Proto-PC	5	5		50	-40	85	N/A	N/A	0	70	N/A	N/A
	Thermocouple (data acq)	5	5	0	50	-25	85	N/A	N/A	-25	85	N/A	N/A
	Parvus Relay (Data acq)	5	5	0	1500	-40	85	10	85	-40	85	10	85
	Diamond DAQ	5	5	0	200	-45	85	5	95	-45	85	5	95
	High Efficiency PC-104 Power Supply	3	40	0	15000	-40	85	N/A	N/A	-40	85	N/A	N/A
	DiskOnChip 2000DIP (Harddrive)	5	5	0.006	40	-40	85	10	90	-40	85	10	90
	Wire M22759 22AWG	N/A	N/A	0	9500	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	High Efficiency PC-104 Power Supply (24VDC Suply)	6	40		50	-40	85	N/A	N/A	-40	85	N/A	N/A
	D-Sub Connectors	N/A	N/A	0	7000	-55	105	N/A	N/A	-55	105	N/A	N/A
	Ribbon Cable	N/A	N/A	0	6800	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Heaters													
	Heaters (3.5x2.75in)	N/A	N/A	0	13500	-200	200	N/A	N/A	-200	200	N/A	N/A
	Heaters (3x5in)	N/A	N/A	0	13500	-200	200	N/A	N/A	-200	200	N/A	N/A
	Heaters (1x4in)	N/A	N/A	0	13500	-200	200	N/A	N/A	-200	200	N/A	N/A
	Oven Controller	4.75	60	0	4000	-40	70	N/A	N/A	-40	70	N/A	N/A
	Oven Insulation (ZOTEFOAM 38 HD)	N/A	N/A	N/A	N/A		160	N/A	N/A		290	N/A	N/A
Power Distribution													
	6 AWG 4P Terminal Strip	0	300	0	15000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	8 AWG 10P Terminal Strip	0	300	0	15000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	22AWG 6P Terminal Strip	0	300	0	50000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	24 AWG 5P Terminal Strip	0	300	0	50000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	5-Fuse Block	0	300	N/A	N/A	-40	110	N/A	N/A	-40	110	N/A	N/A
	4-Fuse Block	0	300	N/A	N/A	-40	110	N/A	N/A	-40	110	N/A	N/A
	2 Fuse Block	0	300	N/A	N/A	-40	110	N/A	N/A	-40	110	N/A	N/A
	4 Amp Fuses	N/A	N/A	0	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	3 Amp Fuses	N/A	N/A	0	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	2 Amp Fuse	N/A	N/A	0	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	5 Amp Fuse	N/A	N/A	0	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	20 Amp Fuse	N/A	N/A	0	20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	6 Amp Fuse	N/A	N/A	0	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	EMI Filter (FME28-461/ES)	0	28	0	15000	-55	125	N/A	N/A	-65	150	N/A	N/A
	Solid State Relays: output	1	50										
	Solid State Relays: input	3	32	N/A	N/A	-20	80	N/A	N/A	-40	100	N/A	N/A
	Transformers	-6.3	6.3	0	600	-40	105	N/A	N/A	-40	105	N/A	N/A
	YCL Latching Relay	0	29	0	30	-70	125	N/A	N/A	-70	125	N/A	N/A
	Diodes	0	40	0	5000	-55	150	N/A	N/A	-55	150	N/A	N/A
	Resistors (1ohm)	N/A	N/A	N/A	N/A	-55	250	N/A	N/A	-55	250	N/A	N/A
	8 AWG Wire	N/A	N/A	0	81000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pressure System													
	Pressure Transducer	20	36	200	360	-54	121	N/A	N/A	-54	121	N/A	N/A
	Pressure Transducer Wire	N/A	N/A	0	95000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Solenoid	18	24		900	-40	105	N/A	N/A	-40	105	N/A	N/A
Imaging System													
	Lights - LEDs	0.7	13	0	700	-40	110	N/A	N/A	-40	120	N/A	N/A
	Cameras	8.5	12	0	100	-20	100	N/A	N/A	-20	100	N/A	N/A

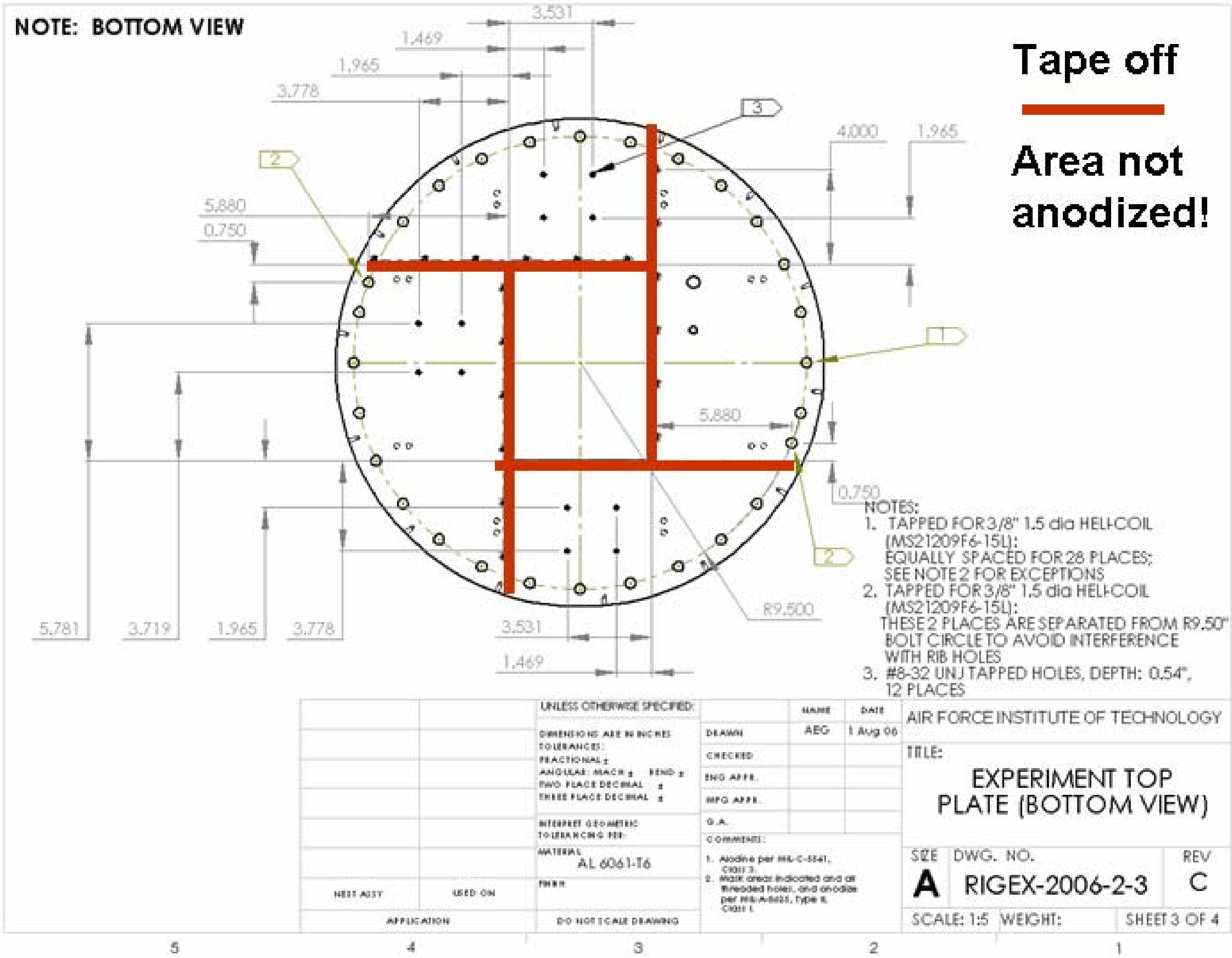
Appendix H: RIGEX Anodizing and Alodining Instructions

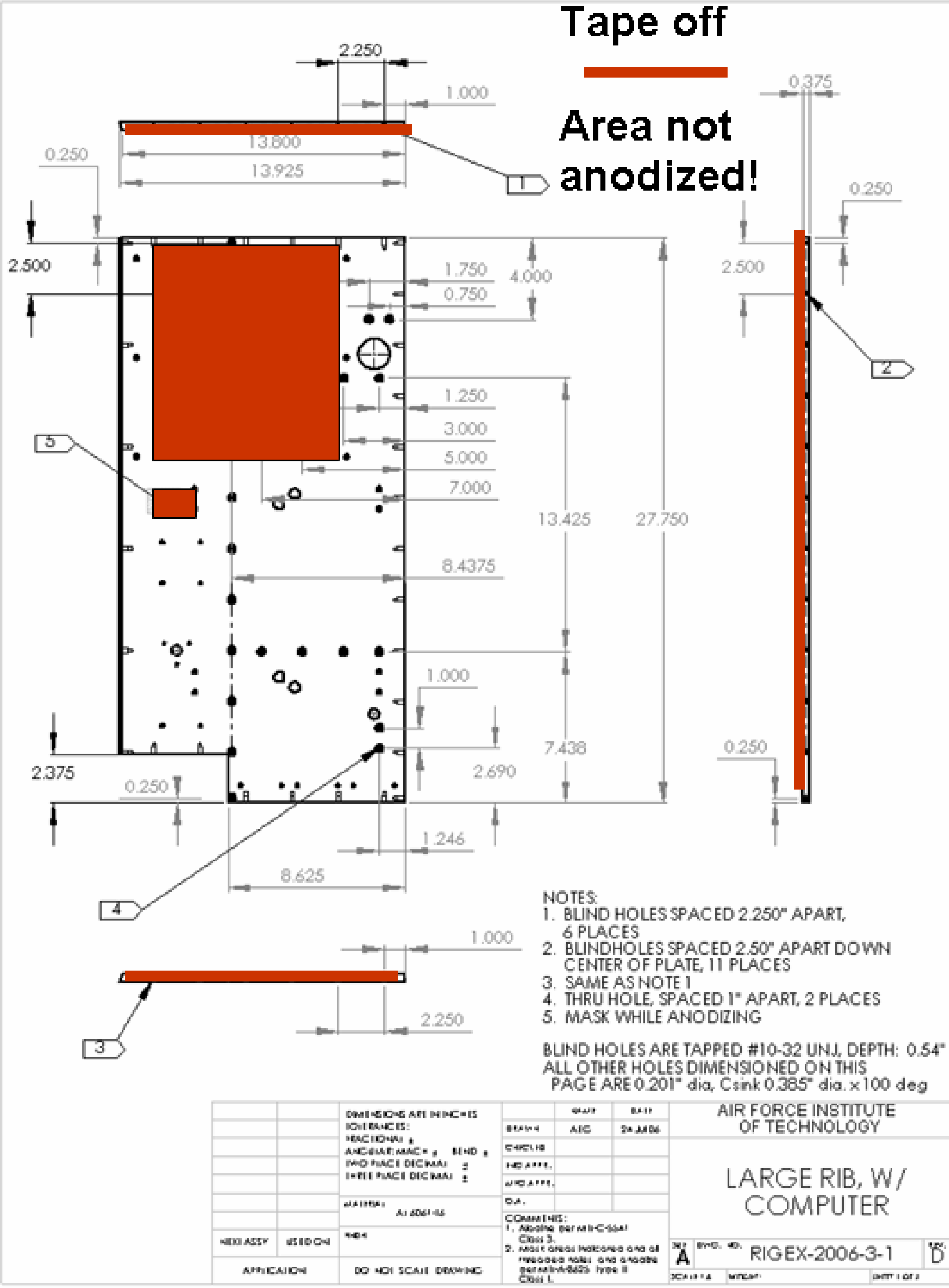
The following figures represent the instructions provided to TechMetals, Inc. for the treatment of RIGEX's aluminum structure. All parts were alodined by TechMetals. After alodining, all threaded and non-threaded holes smaller than a half inch in diameter were masked before anodizing.


NOTE: TOP VIEW
1
2
10.607
5.303
5.303
10.607
R11.625
0.275
1.250
0.275
0.750
24.000
1.500
Entire piece alodine only!
NOTES:
1. 0.272 dia. thru
Cbore .5625 dia x .75 depth
2. TAPPED FOR #10-32 HELI-COIL
(MS21209F1-20)
SPACED EQUALLY AROUND
RECTANGULAR HOLE (8 PLACES)
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
AL 6061-T6
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
AEG
21 Aug 06
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1. Alodine per MIL-C-5541, Class 3.
2. Mask areas indicated and all threaded holes, and anodize per MIL-A-8625, Type II, Class I.
AIR FORCE INSTITUTE OF TECHNOLOGY
TITLE:
CAPE MOUNTING PLATE
(TOP VIEW)
SIZE
A
DWG. NO.
RIGEX-2006-1-1
REV
D
SCALE: 1:6
WEIGHT:
SHEET 1 OF 3
5
4
3
2
1



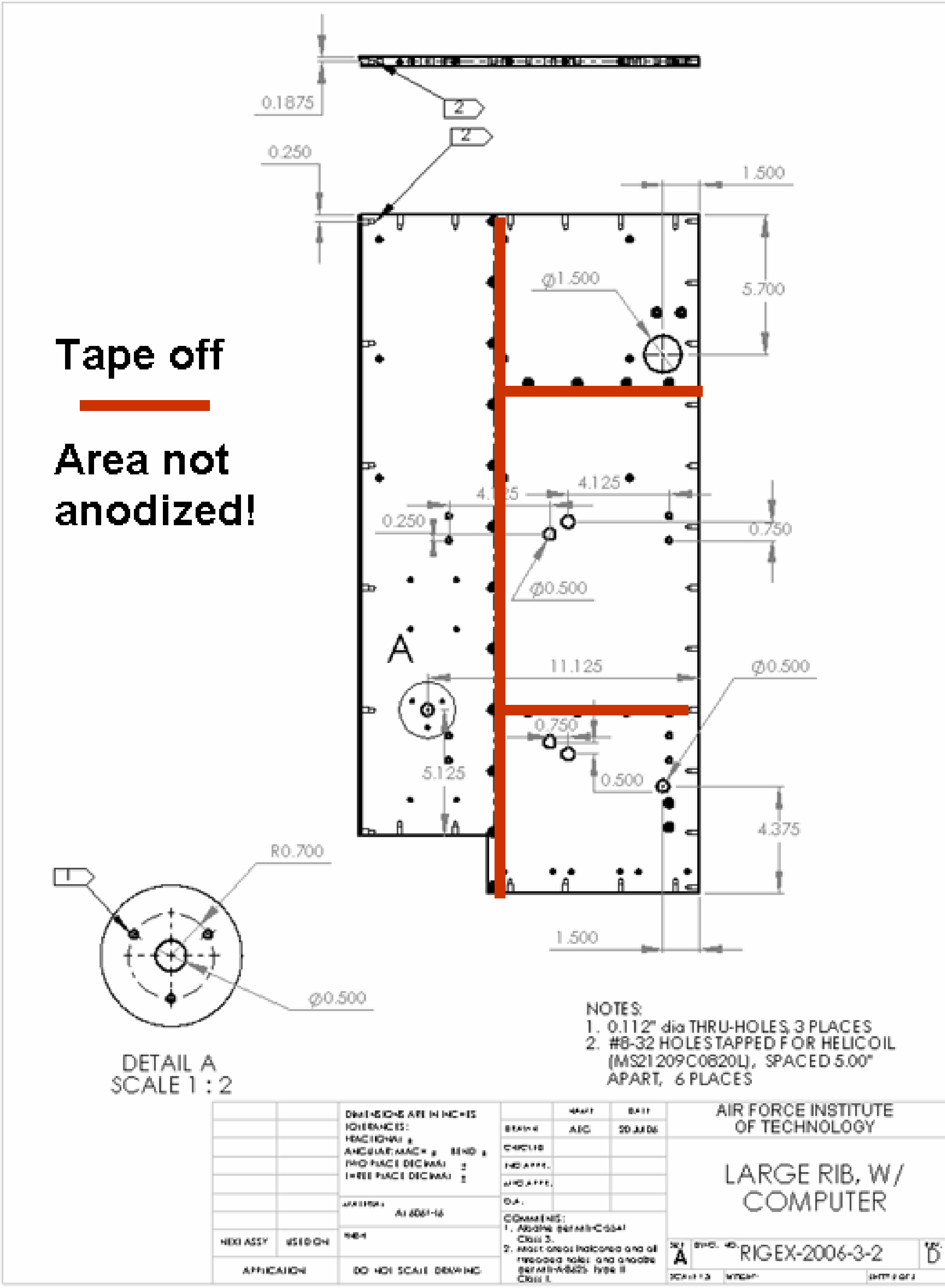
NOTE: TOP VIEW
0.625
0.1875
1.000
0.1875
Ø20.500
0.1875
0.1875
1.000
R9.500
4
3
5
Tape off
Area not anodized!
NOTES:
1. ALL HOLES SPACED 2.25" APART, 6 PLACES
2. ALL HOLES SPACED 2.125" APART, 6 PLACES APART
3. SAME AS NOTE 1
4. SAME AS NOTE 2
5. BOLT CIRCLE IS TAPPED FROM TOP FOR 3/8" 1.5 dia HELI-COIL (MS21209F6-15L)
ALL HOLES DIMENSIONED ON THIS PAGE (WITH THE EXCEPTION OF NOTE 5) ARE: .201 dia. thru, Csink .385 dia x 100 degrees
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
AL 6061-T6
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
AEG
1 Aug 06
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1. Alodine per MIL-C-5541, Class 3.
2. Mask areas indicated and all threaded holes, and anodize per MIL-A-8625, Type II, Class I.
AIR FORCE INSTITUTE OF TECHNOLOGY
TITLE:
EXPERIMENT TOP PLATE (TOP VIEW)
SIZE
A
DWG. NO.
RIGEX-2006-2-1
REV
C
SCALE: 1:5
WEIGHT:
SHEET 1 OF 4
5
4
3
2
1

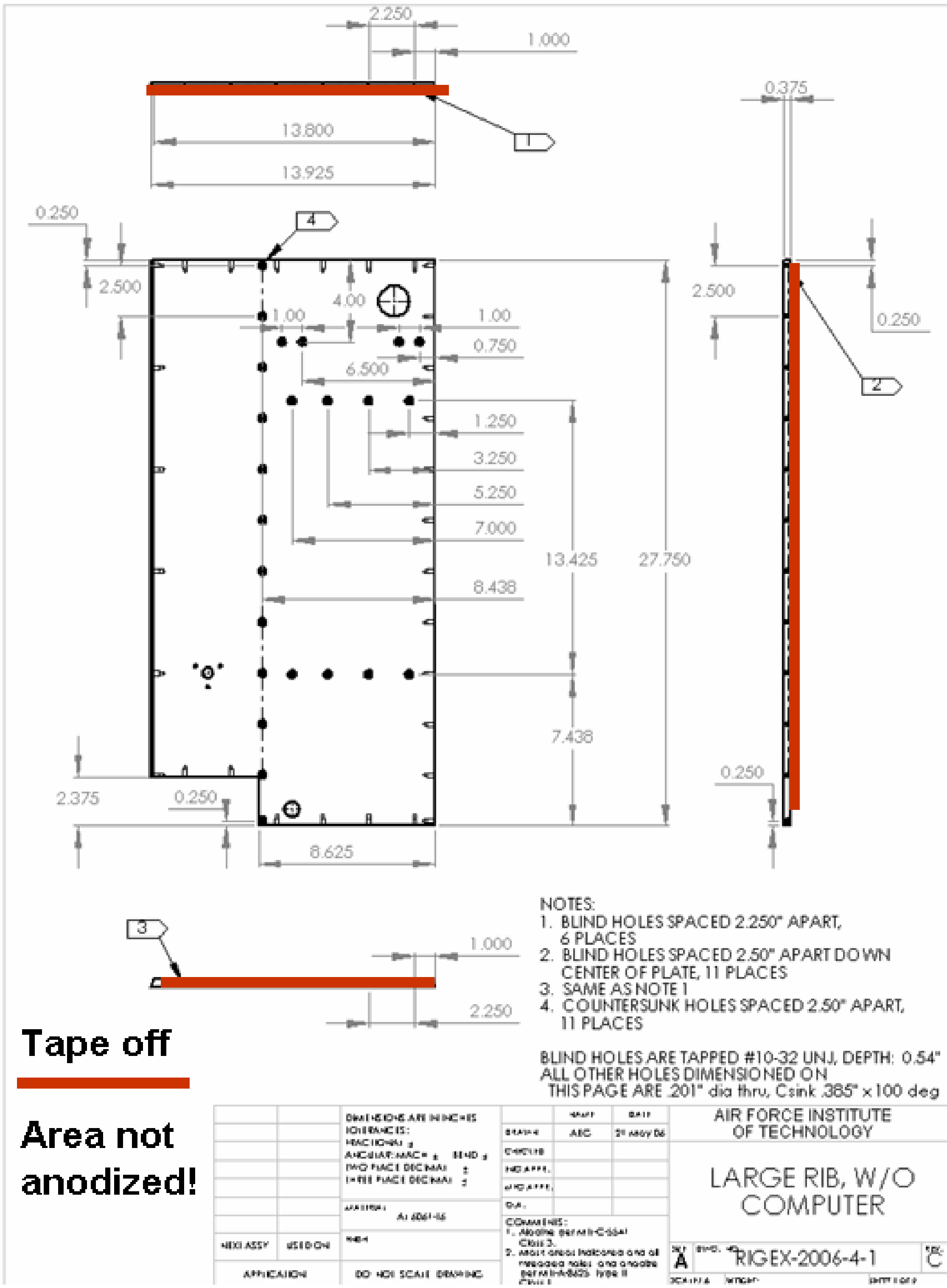

NOTE: BOTTOM VIEW
Tape off
Area not anodized!
3.531
1.469
1.965
3.778
4.000
1.965
5.880
0.750
5.880
0.750
5.781
3.719
1.965
3.778
3.531
1.469
R9.500
NOTES:
1. TAPPED FOR 3/8" 1.5 dia HELI-COIL (MS21209F6-15L); EQUALLY SPACED FOR 28 PLACES; SEE NOTE 2 FOR EXCEPTIONS
2. TAPPED FOR 3/8" 1.5 dia HELI-COIL (MS21209F6-15L); THESE 2 PLACES ARE SEPARATED FROM R9.50" BOLT CIRCLE TO AVOID INTERFERENCE WITH RIB HOLES
3. #8-32 UNJ TAPPED HOLES, DEPTH: 0.54", 12 PLACES
UNLESS OTHERWISE SPECIFIED:
NAME
DATE
DRAWN
AEG
1 Aug 06
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
MATERIAL
AL 6061-T6
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
AIR FORCE INSTITUTE OF TECHNOLOGY
TITLE:
EXPERIMENT TOP PLATE (BOTTOM VIEW)
SIZE
DWG. NO.
A
RIGEX-2006-2-3
REV
C
SCALE: 1:5
WEIGHT:
SHEET 3 OF 4
5
4
3
2
1



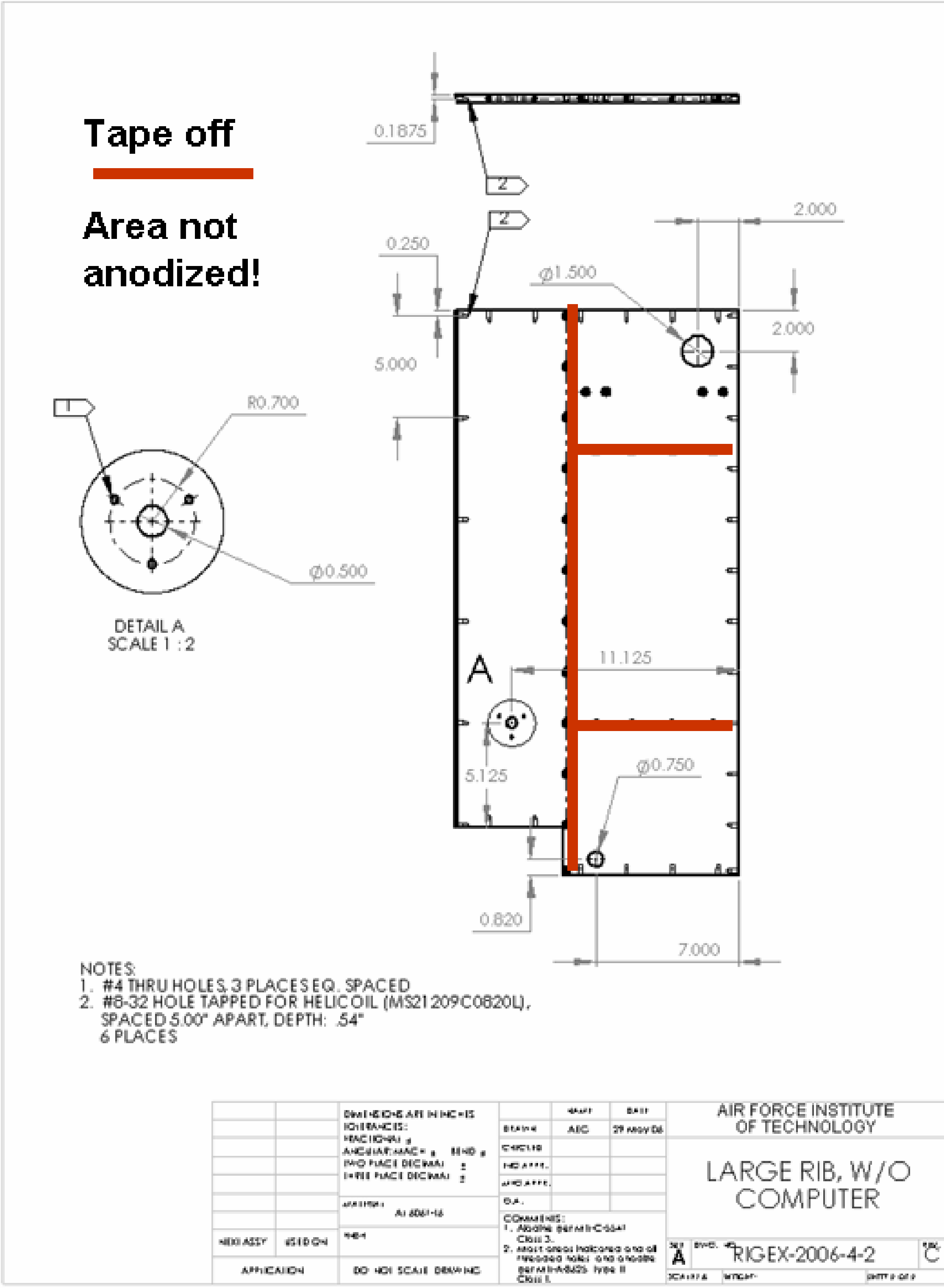
Tape off
Area not anodized!
2.250
1.000
0.375
0.250
13.800
13.925
0.250
2.500
1.750
0.750
4.000
2.500
1.250
3.000
5.000
7.000
13.425
27.750
8.4375
1.000
7.438
2.690
0.250
2.375
0.250
1.246
8.625
1.000
2.250
NOTES:
1. BLIND HOLES SPACED 2.250" APART, 6 PLACES
2. BLINDHOLES SPACED 2.50" APART DOWN CENTER OF PLATE, 11 PLACES
3. SAME AS NOTE 1
4. THRU HOLE, SPACED 1" APART, 2 PLACES
5. MASK WHILE ANODIZING
BLIND HOLES ARE TAPPED #10-32 UNJ, DEPTH: 0.54"
ALL OTHER HOLES DIMENSIONED ON THIS PAGE ARE 0.201" dia, Csink 0.385" dia. x 100 deg
AIR FORCE INSTITUTE OF TECHNOLOGY
LARGE RIB, W/ COMPUTER
A
RIGEX-2006-3-1
D
APPLICATION
DO NOT SCALE DRAWING

Inner side

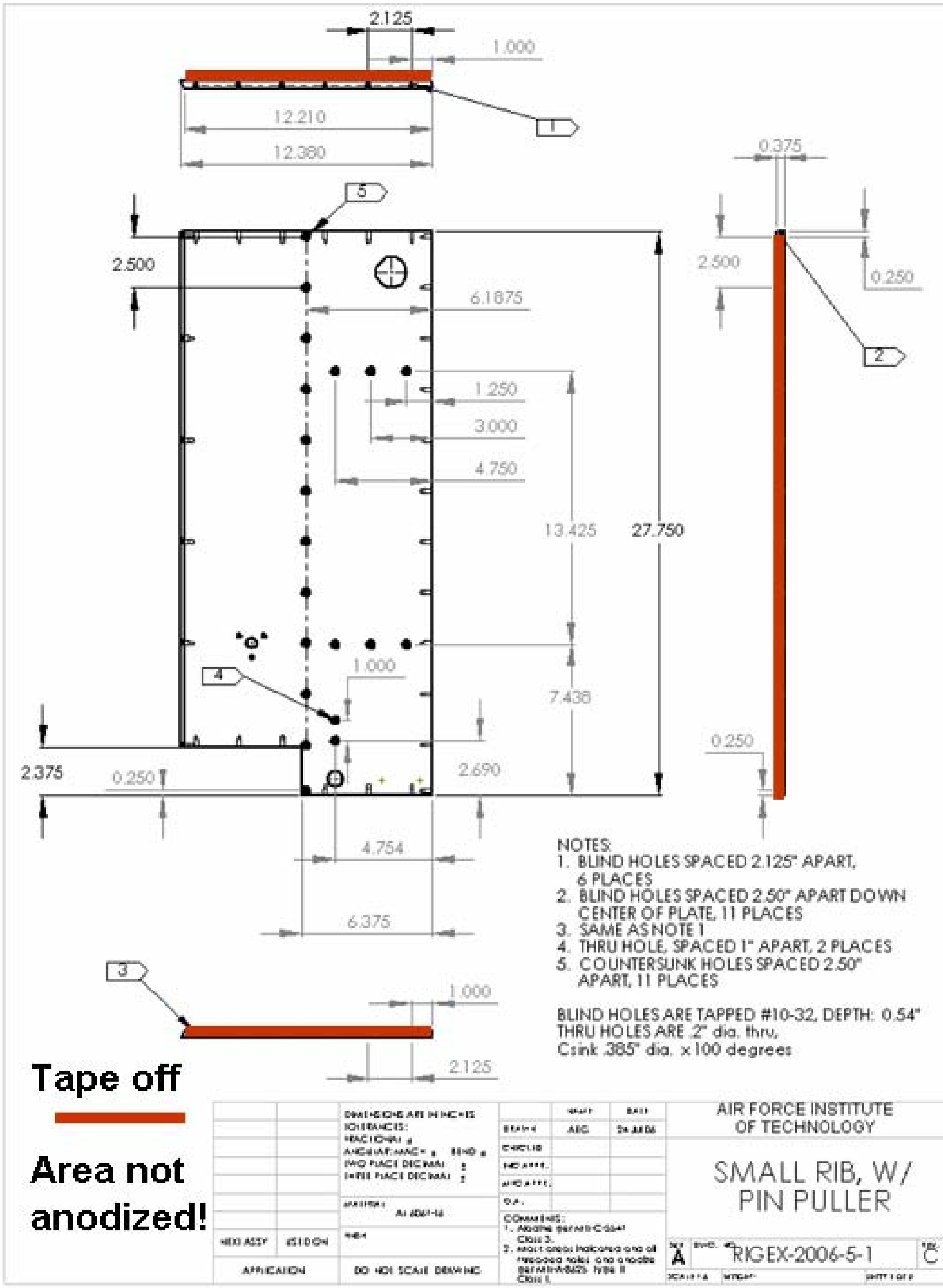

Tape off
Area not anodized!
0.1875
0.250
2
2
1.500
5.700
⌀1.500
4.125
4.125
0.250
0.750
⌀0.500
A
11.125
⌀0.500
0.750
0.500
5.125
4.375
R0.700
1
⌀0.500
1.500
DETAIL A
SCALE 1 : 2
NOTES:
1. 0.112" dia THRU-HOLES, 3 PLACES
2. #8-32 HOLES TAPPED FOR HELICOIL (MS21209C0820L), SPACED 5.00" APART, 6 PLACES
DIMENSIONS ARE IN INCHES
AIR FORCE INSTITUTE OF TECHNOLOGY
LARGE RIB, W/ COMPUTER
A
RIGEX-2006-3-2
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING

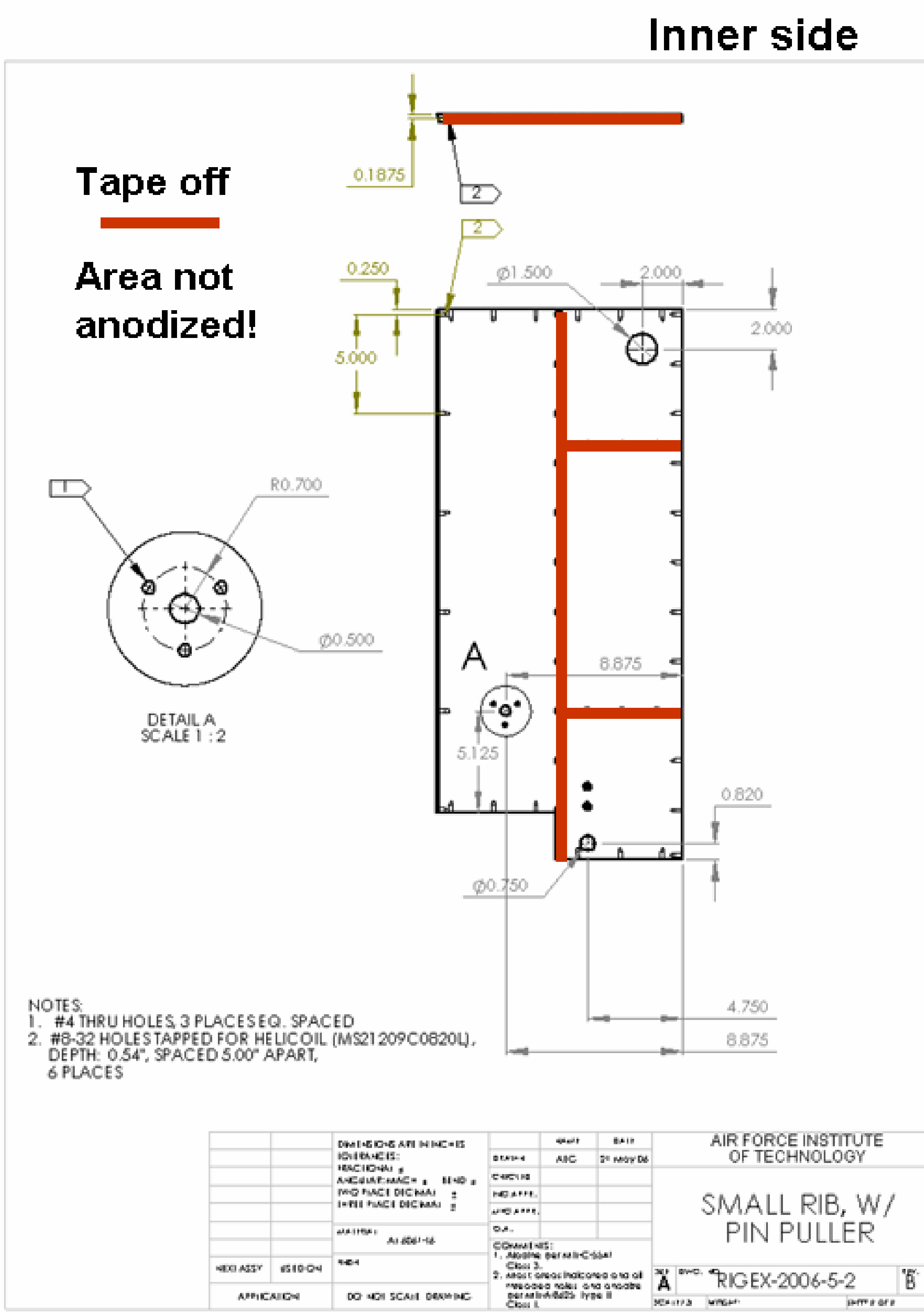

2.250
1.000
13.800
13.925
0.375
0.250
2.500
1.00
4.00
0.750
6.500
1.250
3.250
5.250
7.000
8.438
13.425
27.750
7.438
2.375
8.625
NOTES:
1. BLIND HOLES SPACED 2.250" APART, 6 PLACES
2. BLIND HOLES SPACED 2.50" APART DOWN CENTER OF PLATE, 11 PLACES
3. SAME AS NOTE 1
4. COUNTERSUNK HOLES SPACED 2.50" APART, 11 PLACES
BLIND HOLES ARE TAPPED #10-32 UNJ, DEPTH: 0.54"
ALL OTHER HOLES DIMENSIONED ON THIS PAGE ARE .201" dia thru, Csink .385" x 100 deg
Tape off
Area not anodized!
AIR FORCE INSTITUTE OF TECHNOLOGY
LARGE RIB, W/O COMPUTER
A
RIGEX-2006-4-1
C
AEG
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION

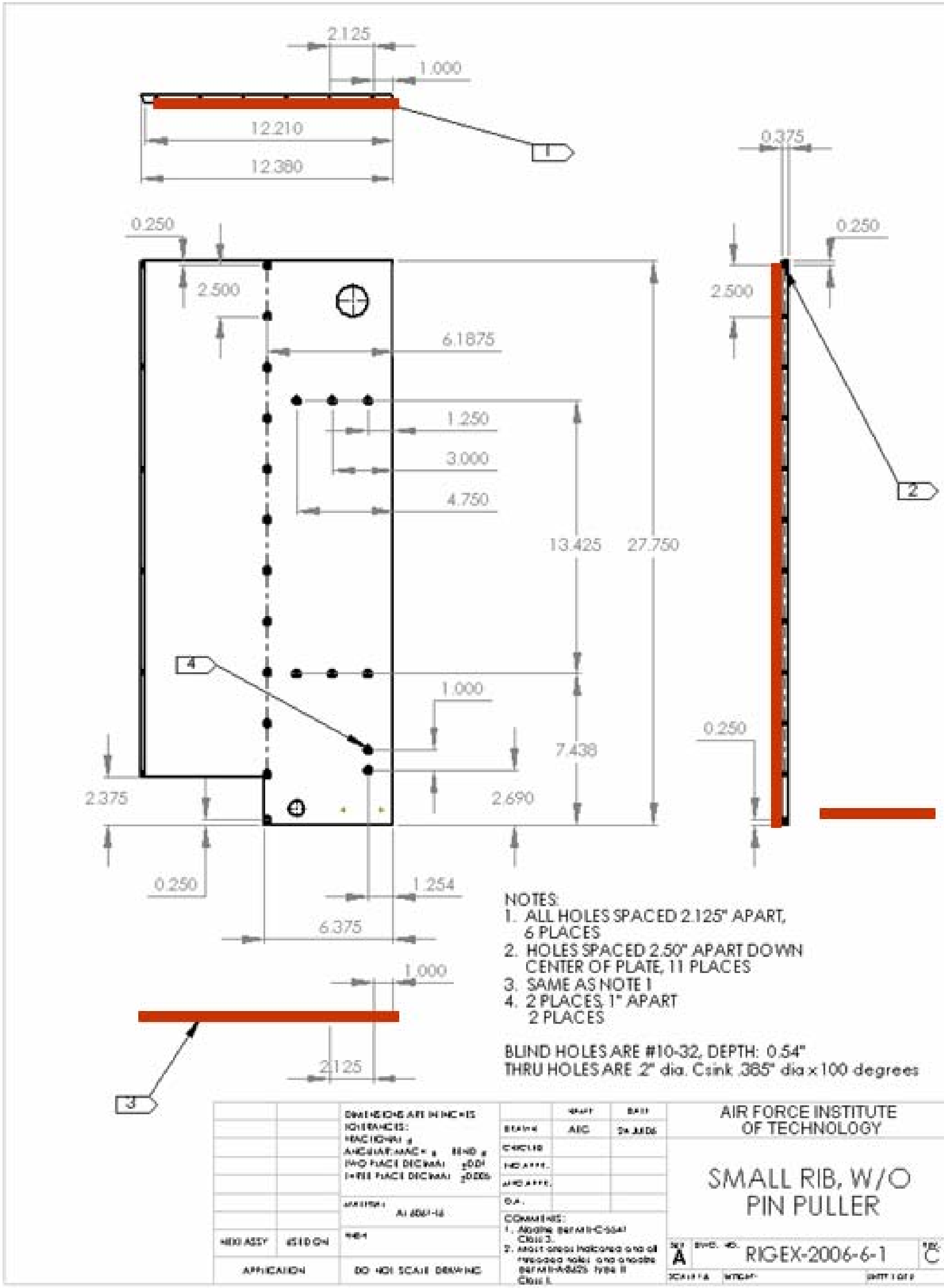
Inner side



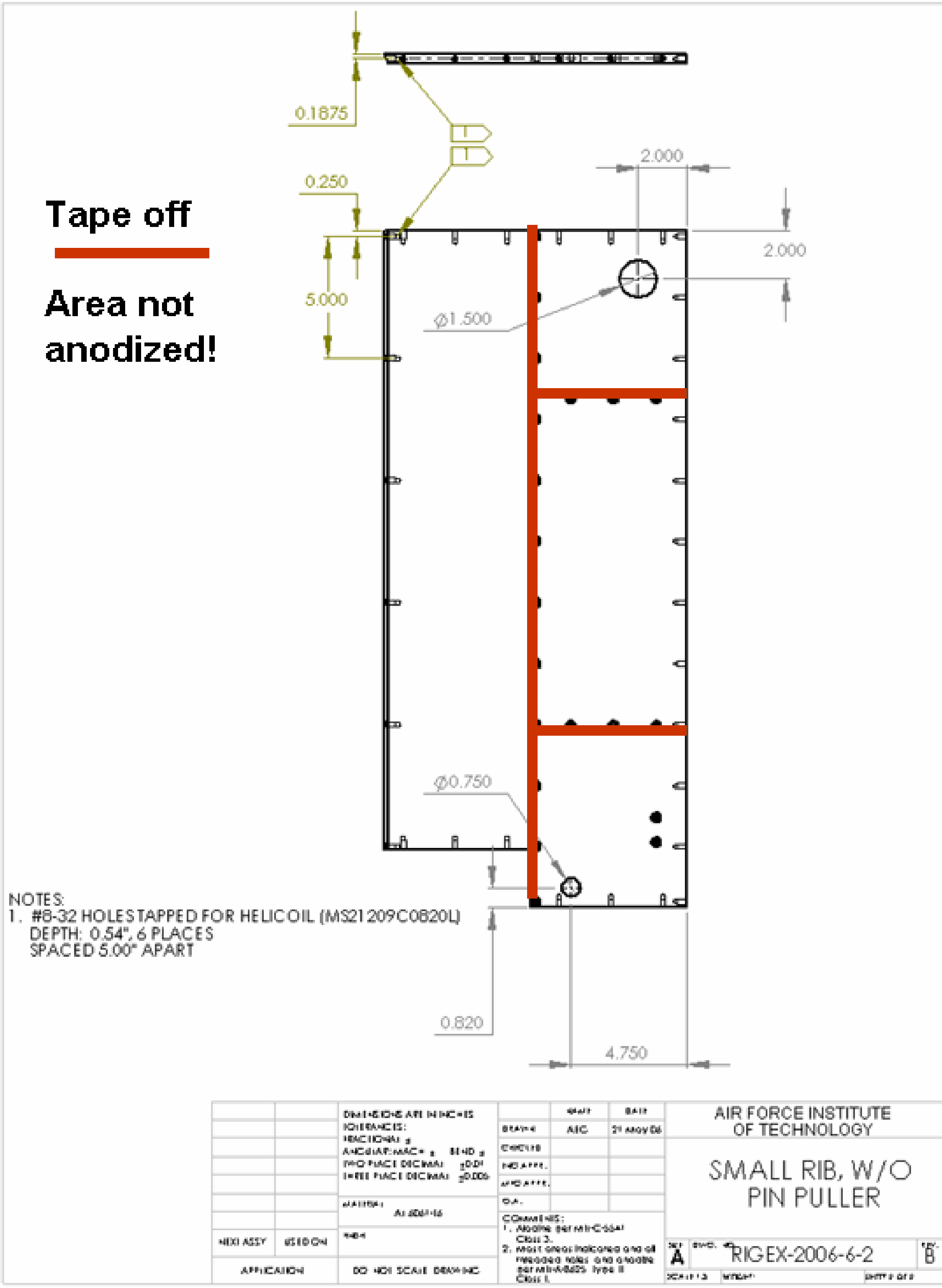
Tape off
Area not anodized!
0.1875
2
2
0.250
2.000
⌀1.500
2.000
5.000
1
R0.700
⌀0.500
DETAIL A
SCALE 1 : 2
A
11.125
5.125
⌀0.750
0.820
7.000
NOTES:
1. #4 THRU HOLES, 3 PLACES EQ. SPACED
2. #8-32 HOLE TAPPED FOR HELICOIL (MS21209C0820L), SPACED 5.00" APART, DEPTH: .54"
6 PLACES
AIR FORCE INSTITUTE OF TECHNOLOGY
LARGE RIB, W/O COMPUTER
A
RIGEX-2006-4-2
C
DO NOT SCALE DRAWING
APPLICATION
NEXT ASSY
USED ON
AL 6061-T6
AEC
29 May 06


2.125
1.000
12.210
12.380
1
5
0.375
2.500
0.250
2
6.1875
1.250
3.000
4.750
13.425
27.750
4
1.000
7.438
2.375
0.250
2.690
0.250
4.754
6.375
3
1.000
2.125
NOTES:
1. BLIND HOLES SPACED 2.125" APART, 6 PLACES
2. BLIND HOLES SPACED 2.50" APART DOWN CENTER OF PLATE, 11 PLACES
3. SAME AS NOTE 1
4. THRU HOLE, SPACED 1" APART, 2 PLACES
5. COUNTERSUNK HOLES SPACED 2.50" APART, 11 PLACES
BLIND HOLES ARE TAPPED #10-32, DEPTH: 0.54"
THRU HOLES ARE .2" dia. thru,
Csink .385" dia. x100 degrees
Tape off
Area not anodized!
AIR FORCE INSTITUTE OF TECHNOLOGY
SMALL RIB, W/ PIN PULLER
A
RIGEX-2006-5-1
C
APPLICATION
DO NOT SCALE DRAWING

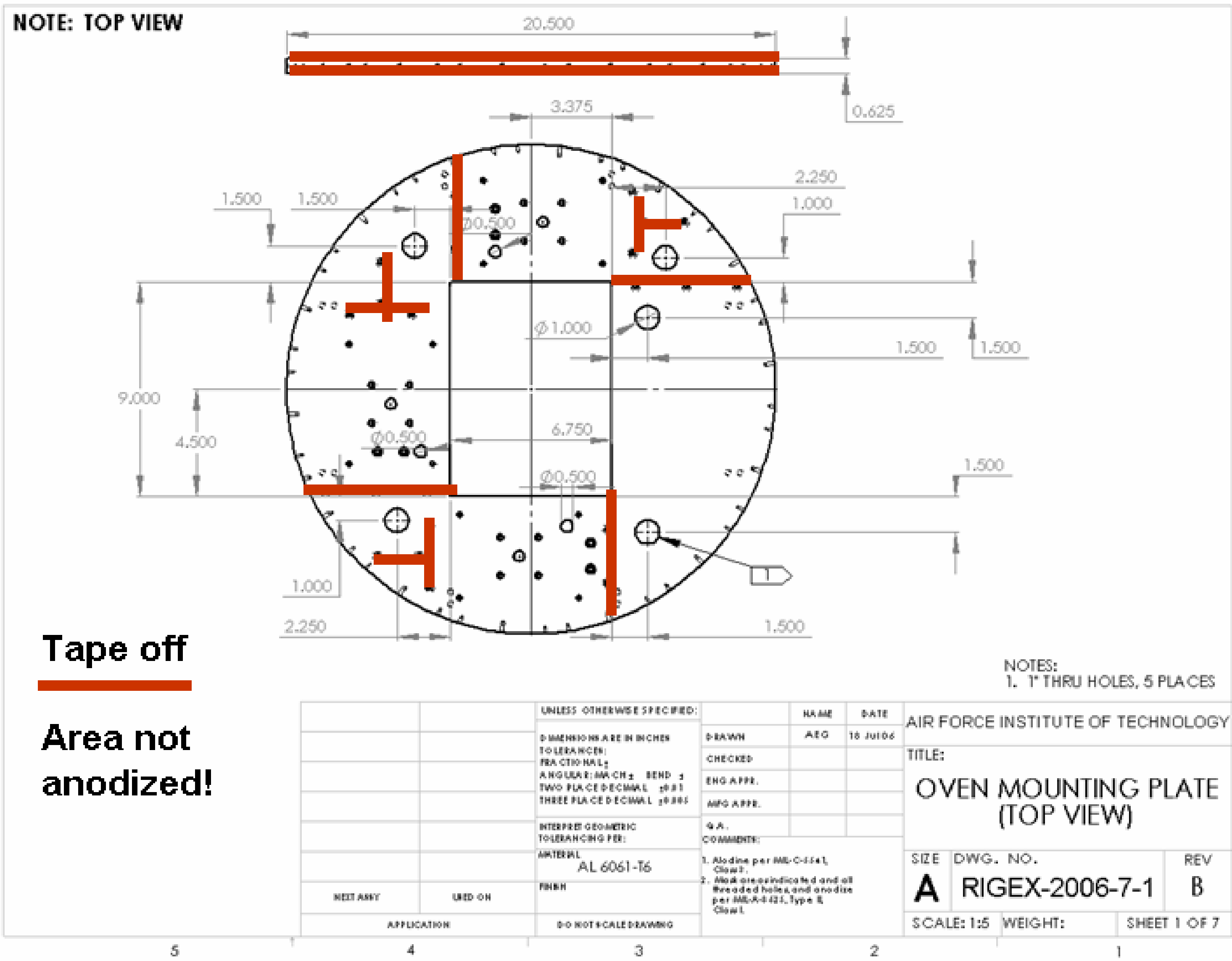

Inner side
Tape off
Area not anodized!
0.1875
2
0.250
ø1.500
2.000
2.000
5.000
R0.700
1
ø0.500
A
8.875
DETAIL A
SCALE 1 : 2
5.125
0.820
ø0.750
4.750
8.875
NOTES:
1. #4 THRU HOLES, 3 PLACES EQ. SPACED
2. #8-32 HOLES TAPPED FOR HELICOIL (MS21209C0820L), DEPTH: 0.54", SPACED 5.00" APART, 6 PLACES
AIR FORCE INSTITUTE OF TECHNOLOGY
SMALL RIB, W/ PIN PULLER
RIGEX-2006-5-2
DO NOT SCALE DRAWING
APPLICATION
NEXT ASSY
A
B

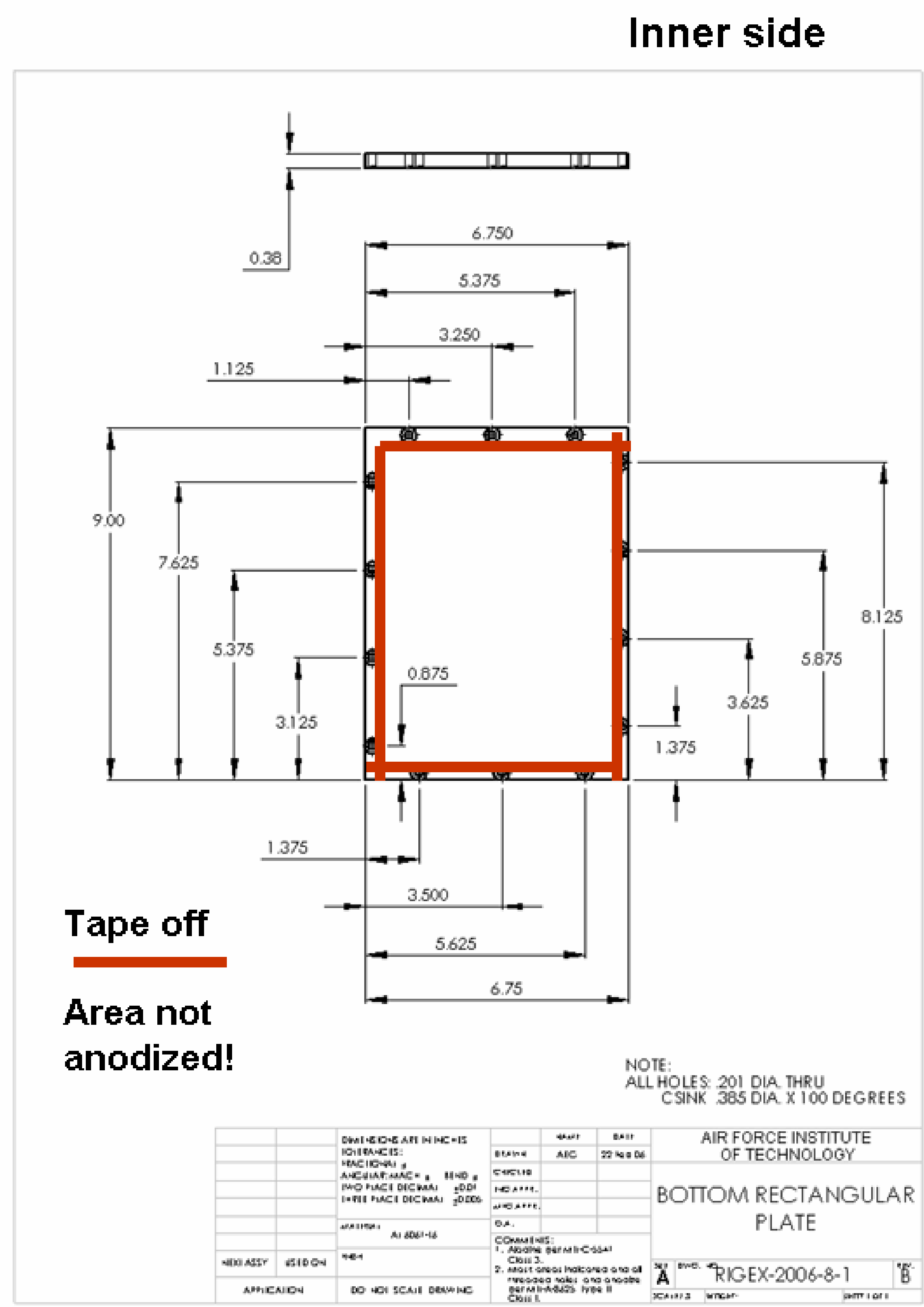

2.125
1.000
12.210
12.380
0.375
0.250
2.500
6.1875
1.250
3.000
4.750
13.425
27.750
1.000
7.438
2.375
2.690
0.250
1.254
6.375
1.000
2.125
1
2
3
4
NOTES:
1. ALL HOLES SPACED 2.125" APART, 6 PLACES
2. HOLES SPACED 2.50" APART DOWN CENTER OF PLATE, 11 PLACES
3. SAME AS NOTE 1
4. 2 PLACES, 1" APART 2 PLACES
BLIND HOLES ARE #10-32, DEPTH: 0.54"
THRU HOLES ARE .2" dia. Csink .385" dia x 100 degrees
AIR FORCE INSTITUTE OF TECHNOLOGY
SMALL RIB, W/O PIN PULLER
A
RIGEX-2006-6-1
C
APPLICATION
DO NOT SCALE DRAWING

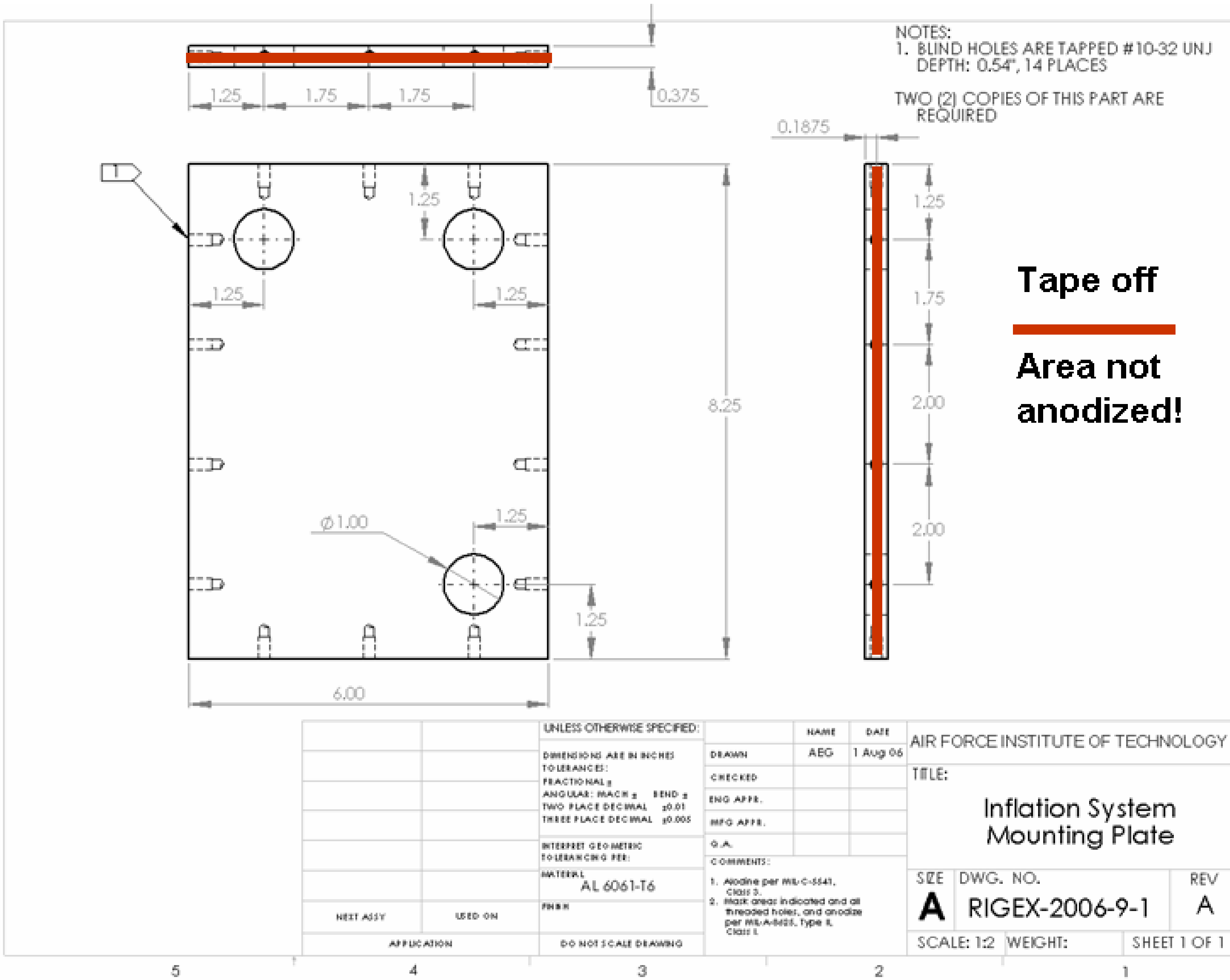
Inner side

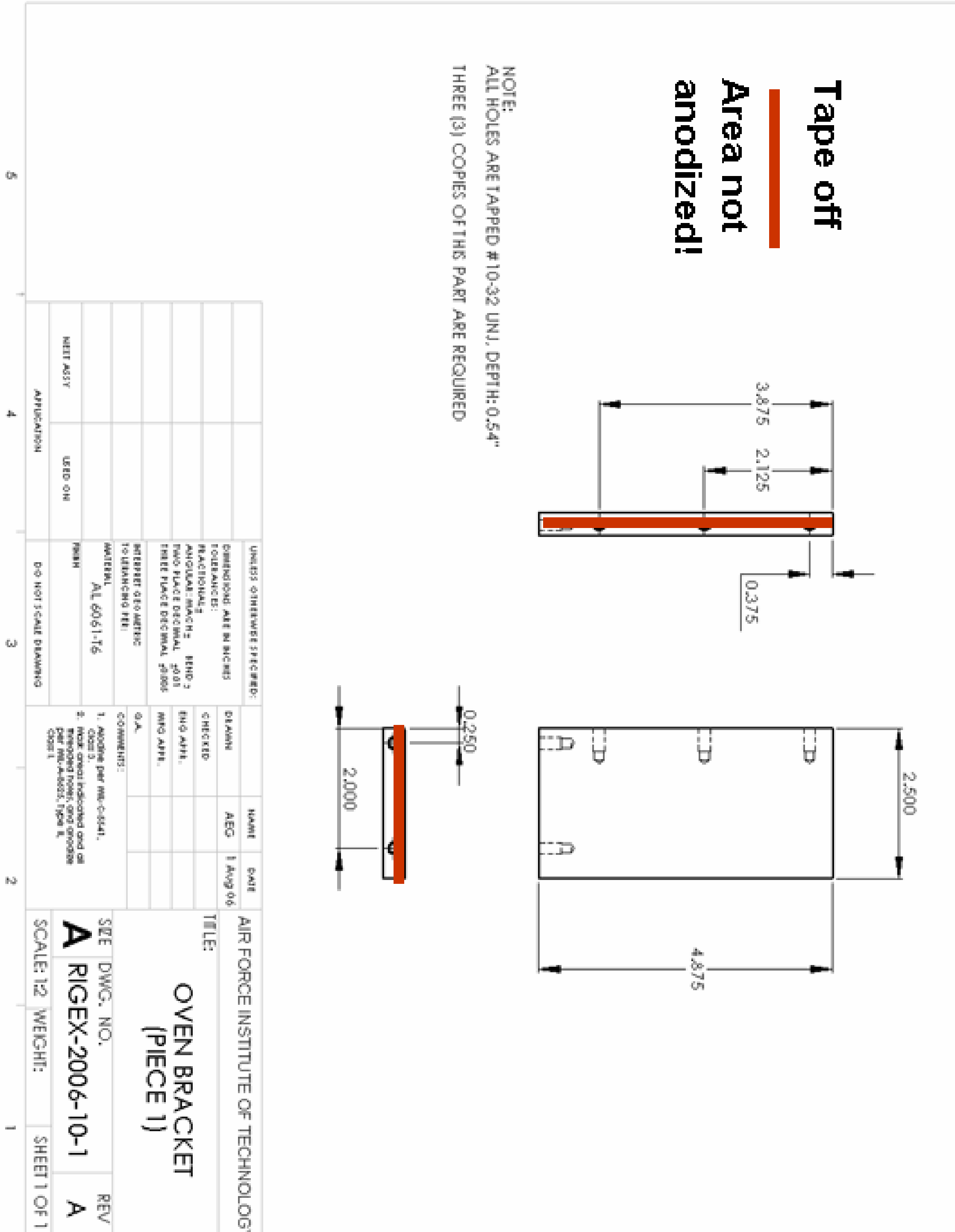


Tape off
Area not anodized!
0.1875
0.250
2.000
2.000
5.000
Ø1.500
Ø0.750
0.820
4.750
NOTES:
1. #8-32 HOLES TAPPED FOR HELICOIL (MS21209C0820L)
DEPTH: 0.54", 6 PLACES
SPACED 5.00" APART
AIR FORCE INSTITUTE
OF TECHNOLOGY
SMALL RIB, W/O
PIN PULLER
RIGEX-2006-6-2
A
B
AIC
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING

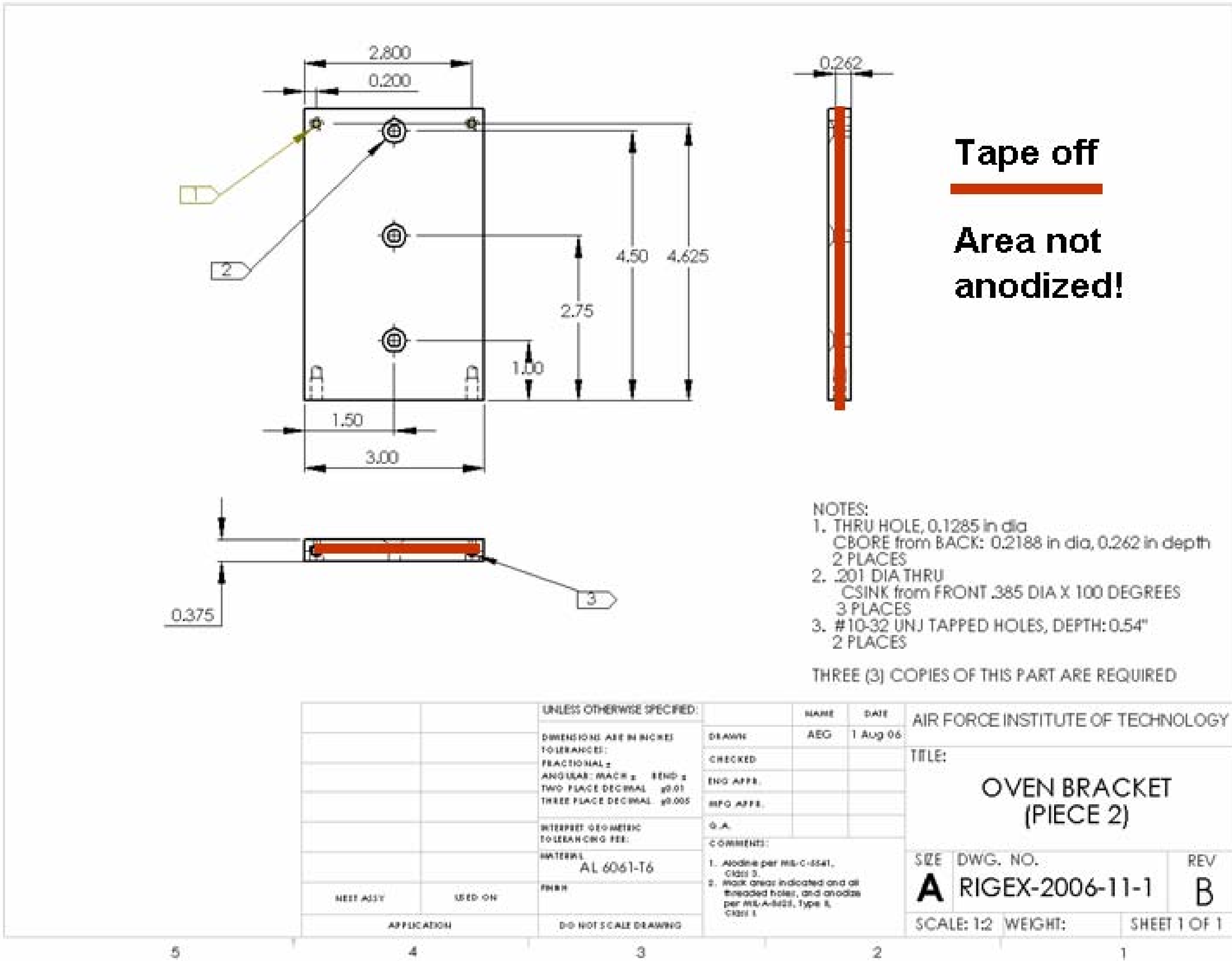

NOTE: TOP VIEW
20.500
0.625
3.375
2.250
1.000
1.500
1.500
Ø0.500
Ø1.000
1.500
1.500
9.000
4.500
Ø0.500
6.750
Ø0.500
1.500
1.000
2.250
1.500
Tape off
Area not anodized!
NOTES:
1. 1" THRU HOLES, 5 PLACES
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
MATERIAL
AL 6061-T6
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
AEG
18 Jul 06
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
AIR FORCE INSTITUTE OF TECHNOLOGY
TITLE:
OVEN MOUNTING PLATE
(TOP VIEW)
SIZE
A
DWG. NO.
RIGEX-2006-7-1
REV
B
SCALE: 1:5
WEIGHT:
SHEET 1 OF 7

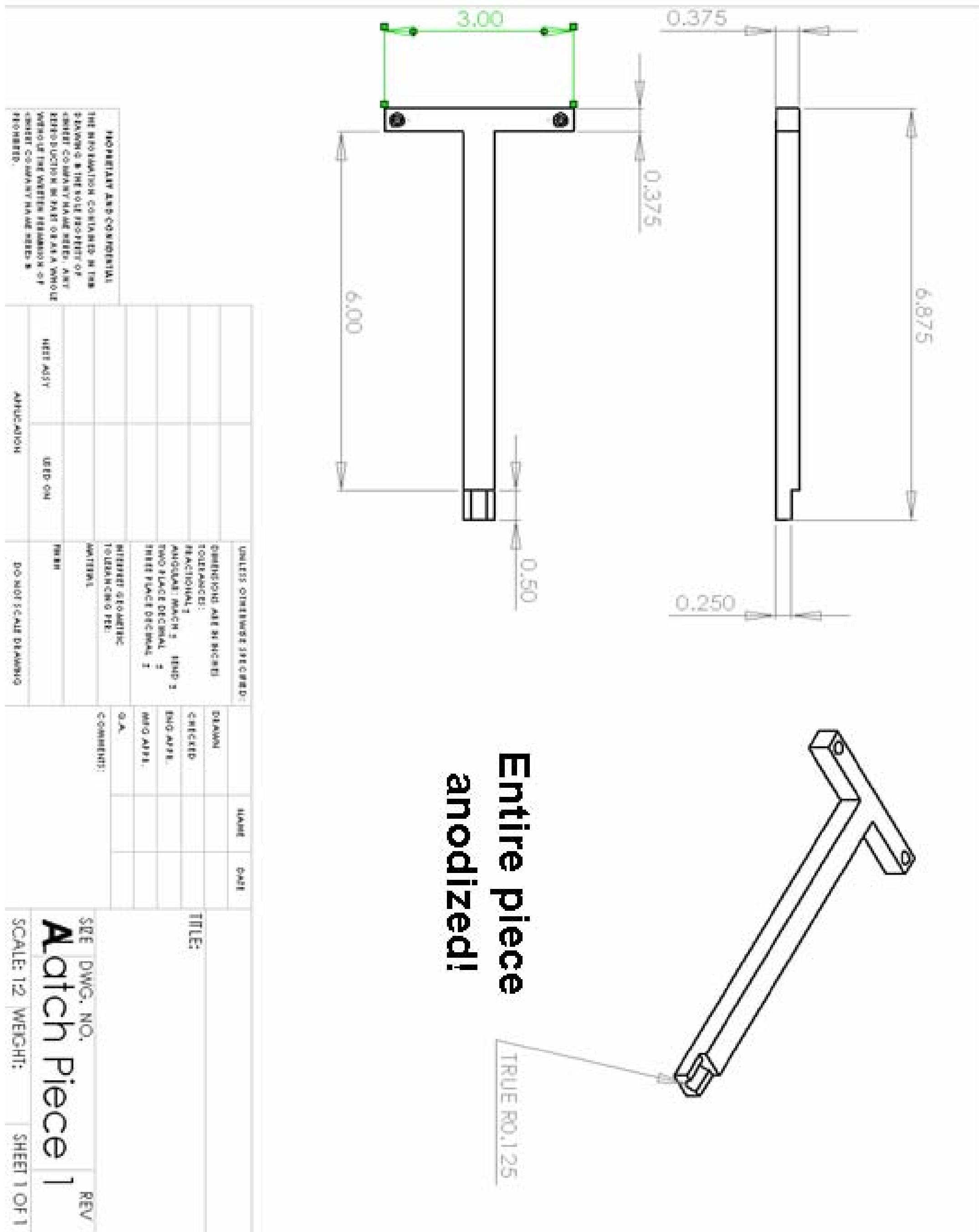

Inner side
0.38
6.750
5.375
3.250
1.125
9.00
7.625
5.375
3.125
0.875
8.125
5.875
3.625
1.375
1.375
3.500
5.625
6.75
Tape off
Area not anodized!
NOTE:
ALL HOLES: .201 DIA. THRU
CSINK .385 DIA. X 100 DEGREES
AIR FORCE INSTITUTE OF TECHNOLOGY
BOTTOM RECTANGULAR PLATE
RIGEX-2006-8-1
A
B
NEXT ASSY
APPLICATION
DO NOT SCALE DRAWING

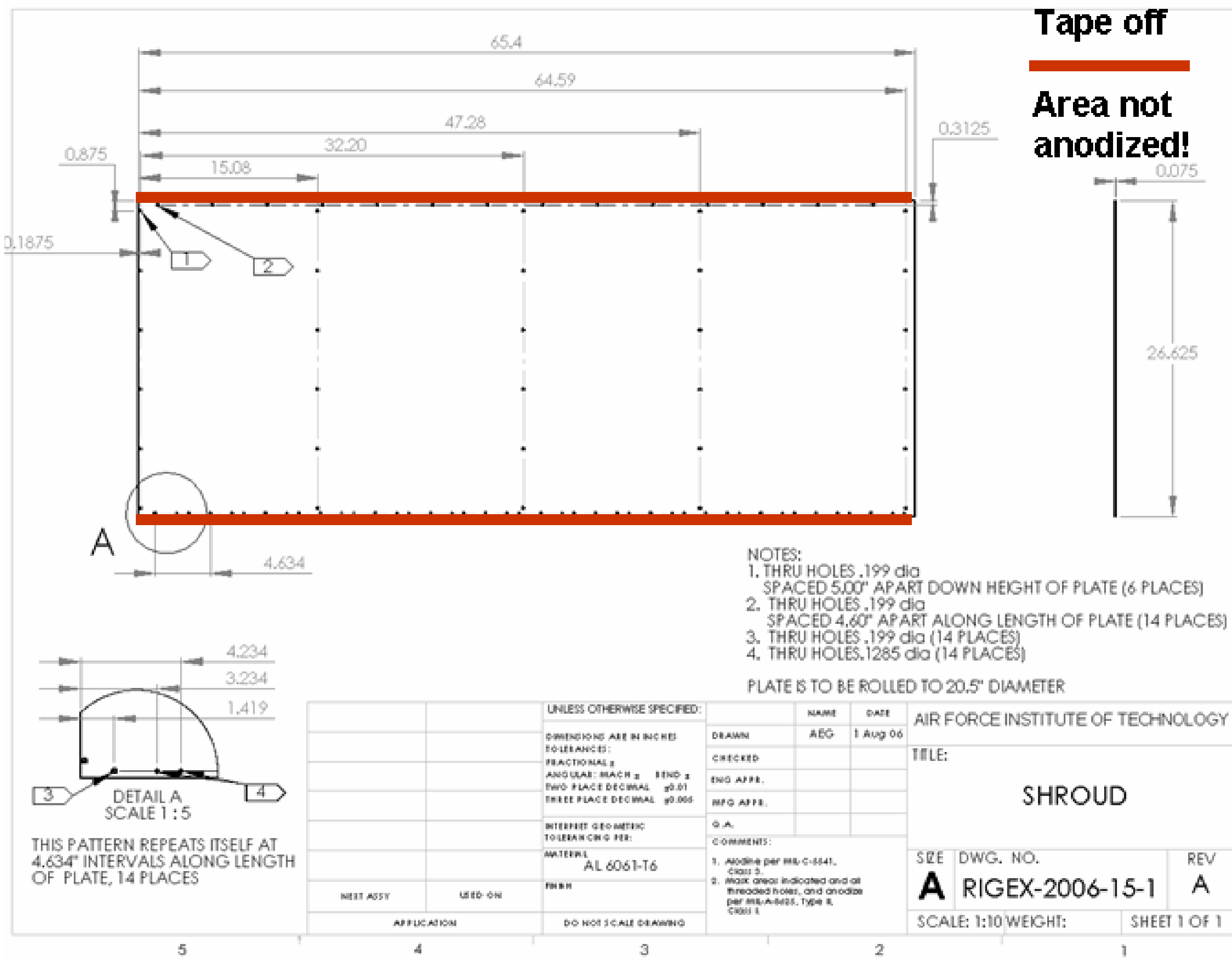

NOTES:
1. BLIND HOLES ARE TAPPED #10-32 UNJ DEPTH: 0.54", 14 PLACES
TWO (2) COPIES OF THIS PART ARE REQUIRED
Tape off
Area not anodized!
1.25
1.75
2.00
0.375
0.1875
8.25
6.00
⌀1.00
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
AL 6061-T6
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
AEG
1 Aug 06
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1. Alodine per MIL-C-5541, Class 3.
2. Mask areas indicated and all threaded holes, and anodize per MIL-A-8625, Type II, Class I.
AIR FORCE INSTITUTE OF TECHNOLOGY
TITLE:
Inflation System Mounting Plate
SIZE
A
DWG. NO.
RIGEX-2006-9-1
REV
A
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1

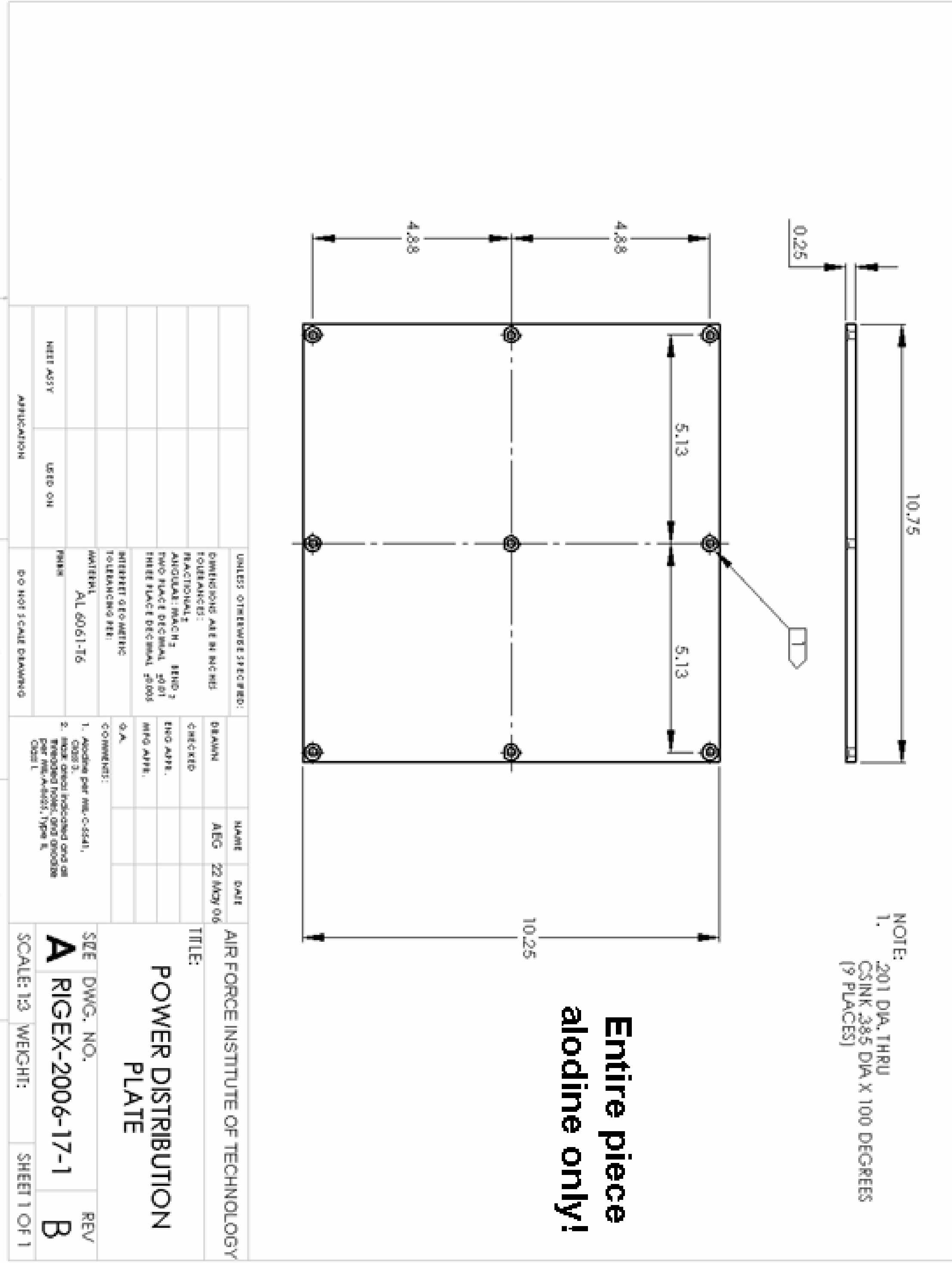


Tape off
Area not anodized!
NOTE:
ALL HOLES ARE TAPPED #10-32 UNJ, DEPTH: 0.54"
THREE (3) COPIES OF THIS PART ARE REQUIRED
3.875
2.125
0.375
2.500
4.875
0.250
2.000
UNLESS OTHERWISE SPECIFIED:
MATERIAL
AL 6061-T6
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
AEG
1 Aug 06
CHECKED
COMMENTS:
AIR FORCE INSTITUTE OF TECHNOLOGY
TITLE:
OVEN BRACKET (PIECE 1)
SIZE
A
DWG. NO.
RIGEX-2006-10-1
REV
A
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1

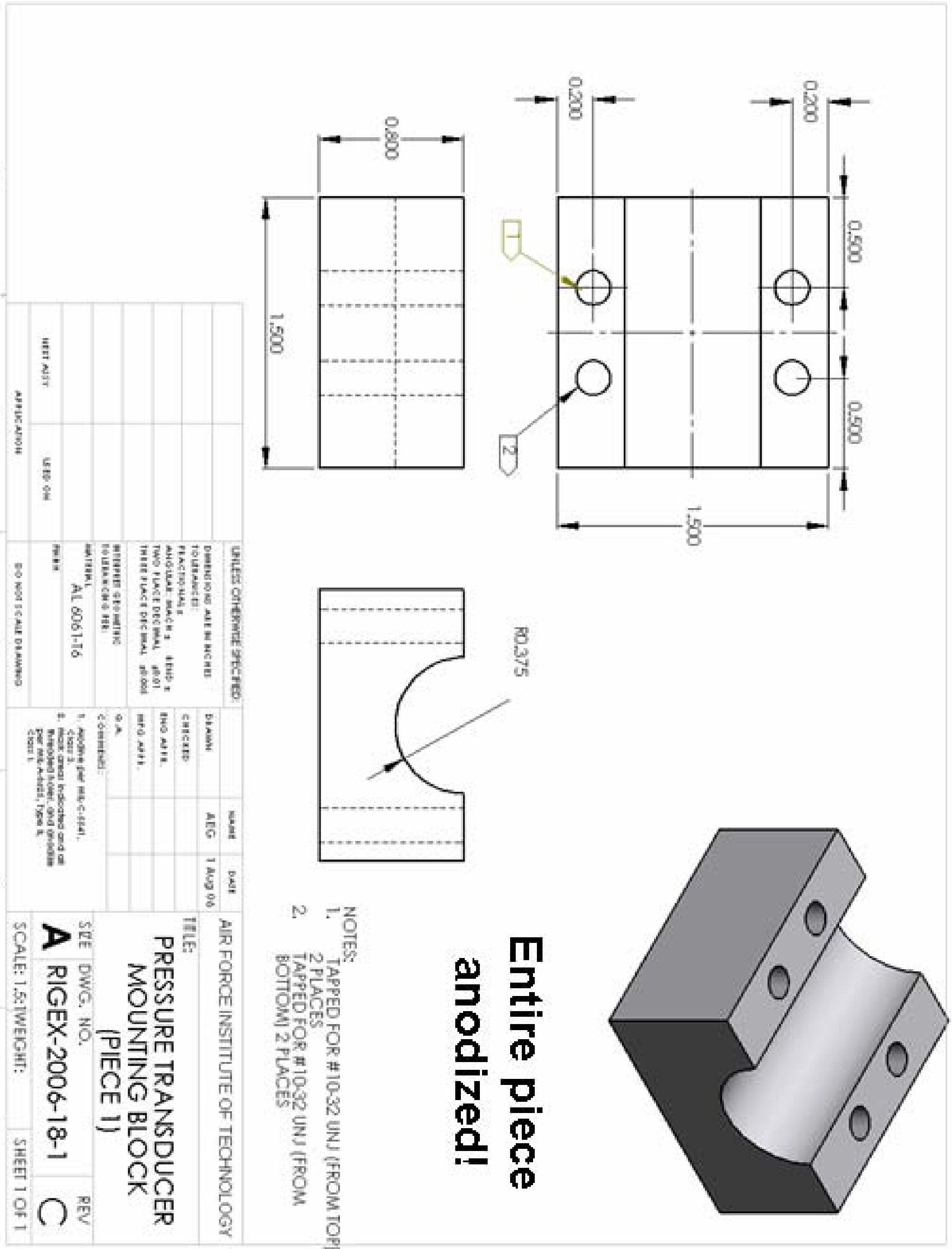

2.800
0.200
4.50
4.625
2.75
1.00
1.50
3.00
0.375
0.262
1
2
3
Tape off
Area not anodized!
NOTES:
1. THRU HOLE, 0.1285 in dia
CBORE from BACK: 0.2188 in dia, 0.262 in depth
2 PLACES
2. .201 DIA THRU
CSINK from FRONT .385 DIA X 100 DEGREES
3 PLACES
3. #10-32 UNJ TAPPED HOLES, DEPTH: 0.54"
2 PLACES
THREE (3) COPIES OF THIS PART ARE REQUIRED
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
AL 6061-T6
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
AEG
1 Aug 06
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1. Alodine per MIL-C-5541, Class 3.
2. Mask areas indicated and all threaded holes, and anodize per MIL-A-8625, Type II, Class 1
AIR FORCE INSTITUTE OF TECHNOLOGY
TITLE:
OVEN BRACKET
(PIECE 2)
SIZE
A
DWG. NO.
RIGEX-2006-11-1
REV
B
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1

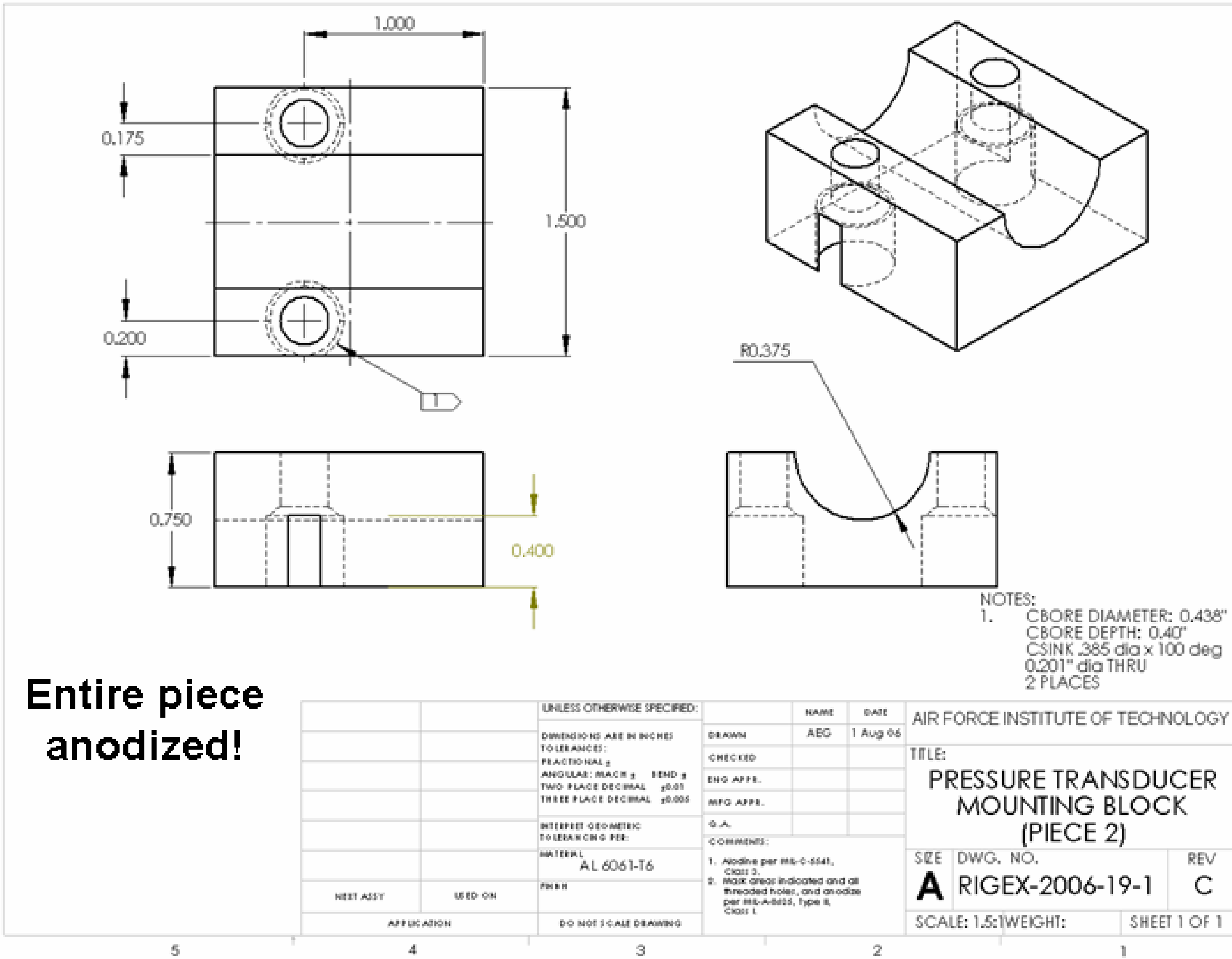

3.00
0.375
0.375
6.00
6.875
0.50
0.250
Entire piece anodized!
TRUE R0.125
TITLE:
SIZE
DWG. NO.
A
Latch Piece 1
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1

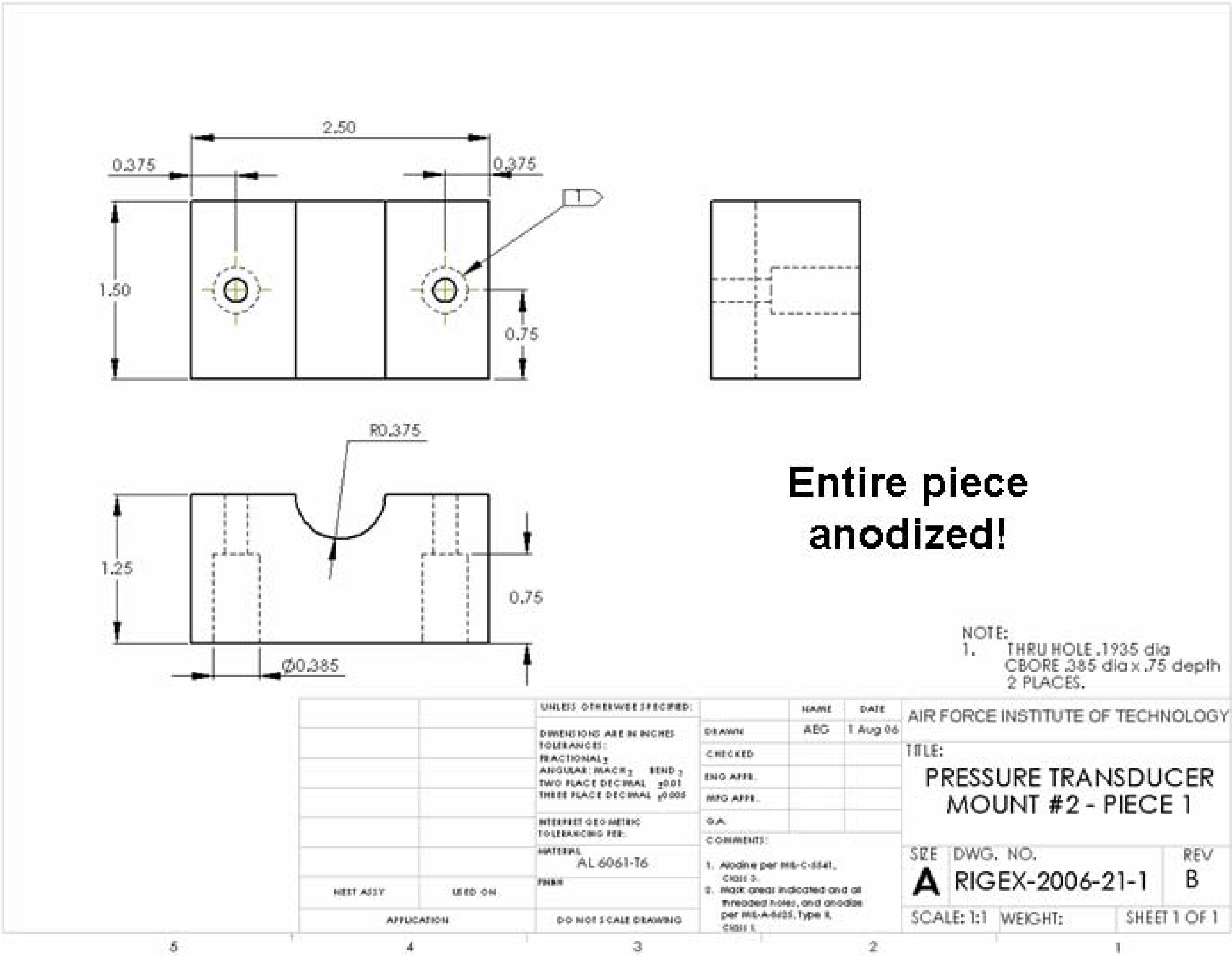

Tape off
Area not anodized!
65.4
64.59
47.28
32.20
15.08
0.875
0.3125
0.075
0.1875
26.625
1
2
A
4.634
NOTES:
1. THRU HOLES .199 dia
SPACED 5.00" APART DOWN HEIGHT OF PLATE (6 PLACES)
2. THRU HOLES .199 dia
SPACED 4.60" APART ALONG LENGTH OF PLATE (14 PLACES)
3. THRU HOLES .199 dia (14 PLACES)
4. THRU HOLES.1285 dia (14 PLACES)
PLATE IS TO BE ROLLED TO 20.5" DIAMETER
4.234
3.234
1.419
3
4
DETAIL A
SCALE 1 : 5
THIS PATTERN REPEATS ITSELF AT 4.634" INTERVALS ALONG LENGTH OF PLATE, 14 PLACES
UNLESS OTHERWISE SPECIFIED:
MATERIAL
AL 6061-T6
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
AEG
1 Aug 06
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
AIR FORCE INSTITUTE OF TECHNOLOGY
TITLE:
SHROUD
SIZE
DWG. NO.
REV
A
RIGEX-2006-15-1
A
SCALE: 1:10
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1

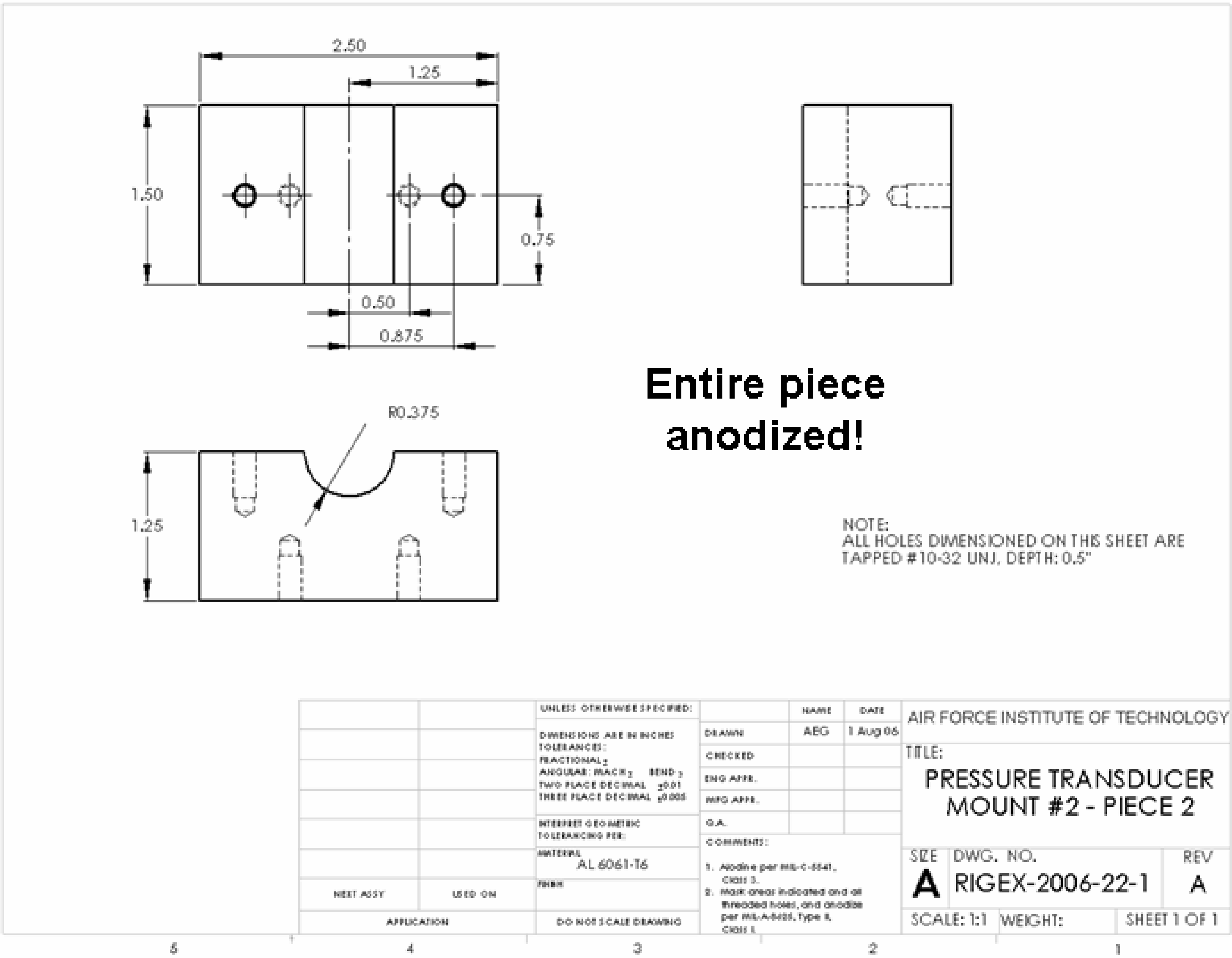


NOTE:
1. .201 DIA THRU
CSINK .385 DIA X 100 DEGREES
[9 PLACES]
Entire piece alodine only!
0.25
4.88
4.88
5.13
5.13
10.75
10.25
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
MATERIAL
AL 6061-T6
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
DRAWN
AEG
22 May 06
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
AIR FORCE INSTITUTE OF TECHNOLOGY
TITLE:
POWER DISTRIBUTION PLATE
SIZE
A
DWG. NO.
RIGEX-2006-17-1
REV
B
SCALE: 1:3
WEIGHT:
SHEET 1 OF 1

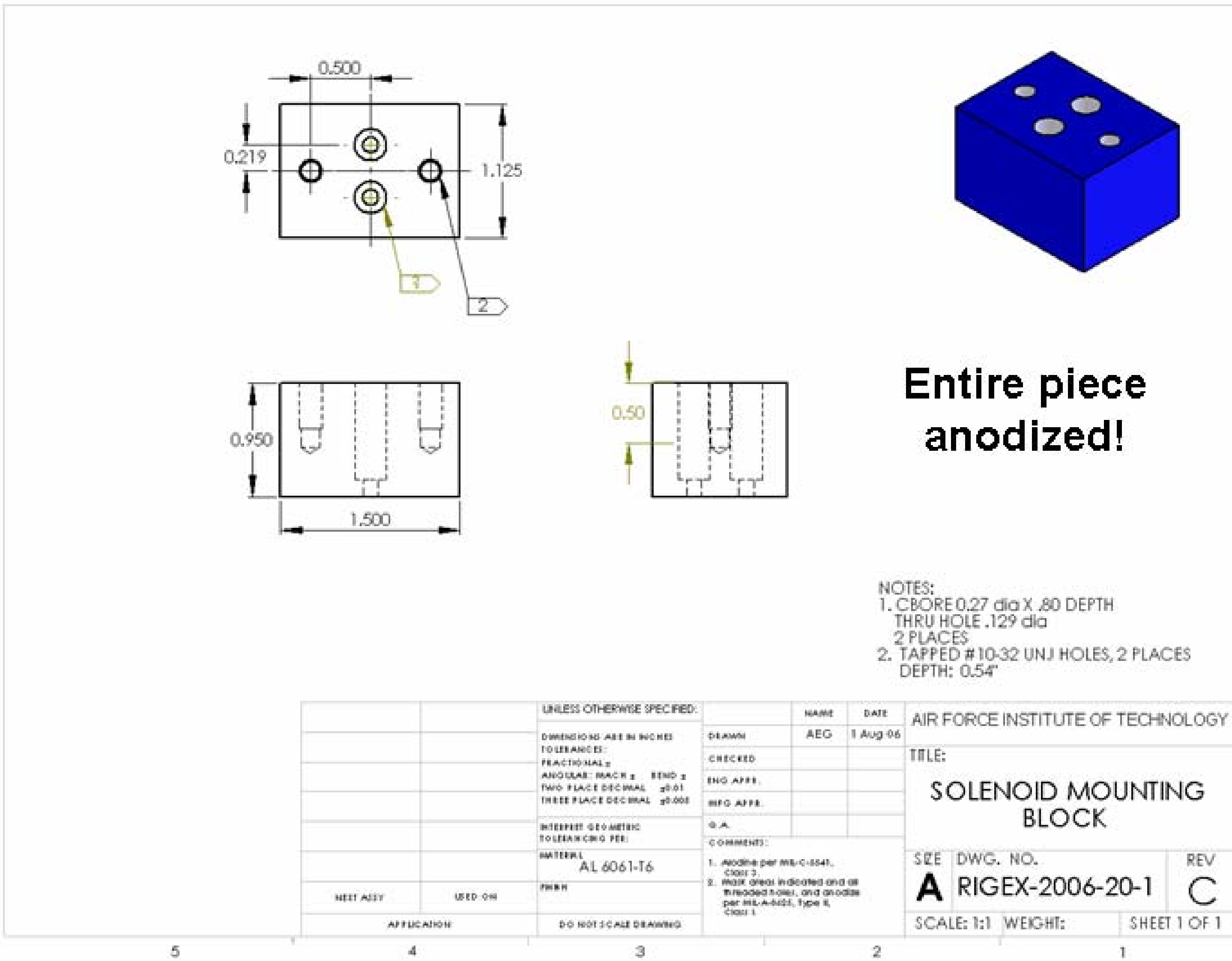

0.200
0.200
0.800
0.500
0.500
1.500
1.500
R0.375
Entire piece anodized!
NOTES:
1. TAPPED FOR #10-32 UNJ (FROM TOP) 2 PLACES
2. TAPPED FOR #10-32 UNJ (FROM BOTTOM) 2 PLACES
UNLESS OTHERWISE SPECIFIED:
MATERIAL
AL 6061-T6
DO NOT SCALE DRAWING
DRAWN
AEG
1 Aug 06
AIR FORCE INSTITUTE OF TECHNOLOGY
TITLE:
PRESSURE TRANSDUCER MOUNTING BLOCK (PIECE 1)
SIZE
A
DWG. NO.
RIGEX-2006-18-1
REV
C
SCALE: 1.5:1
WEIGHT:
SHEET 1 OF 1

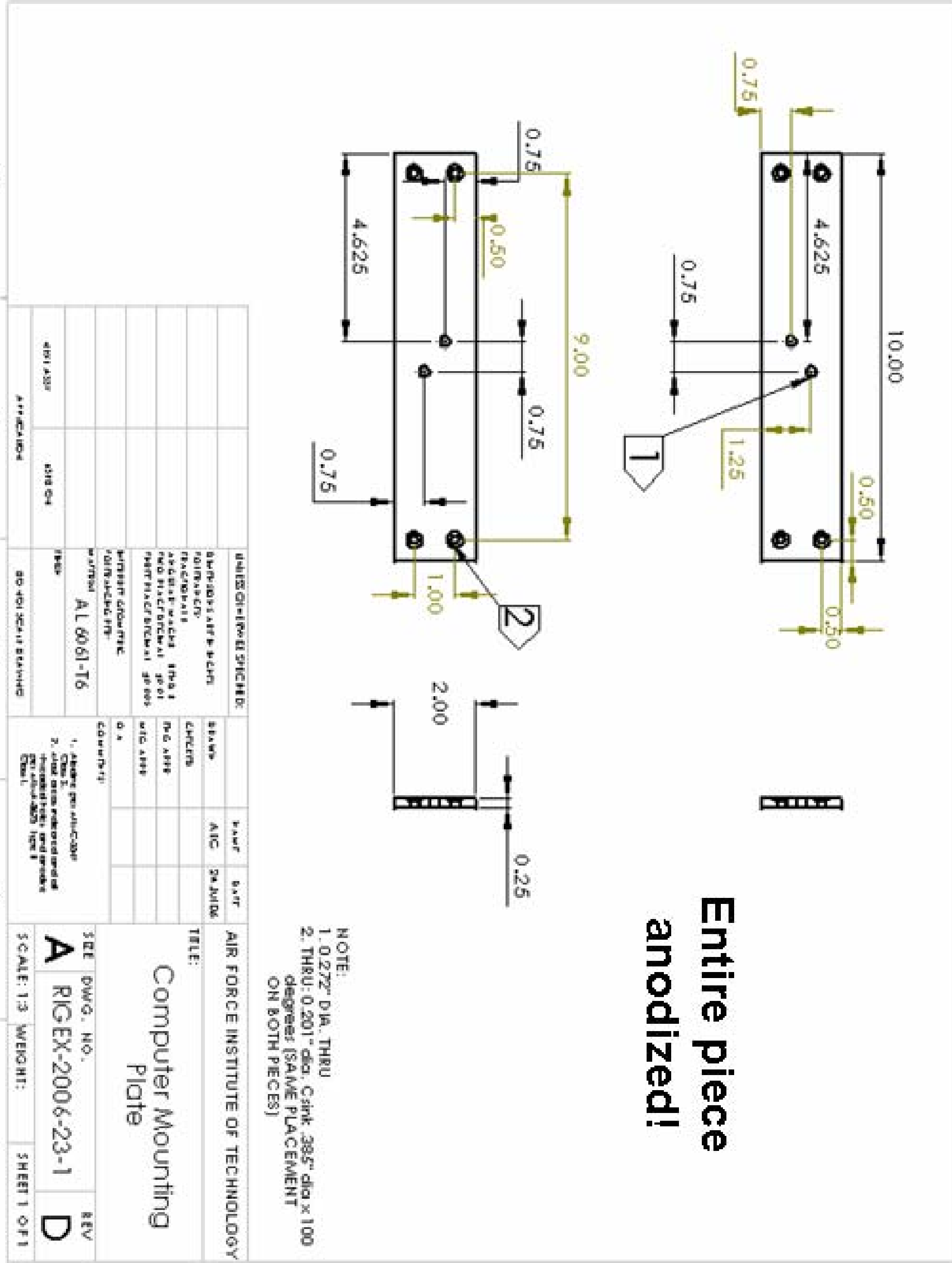

1.000
0.175
1.500
0.200
1
0.750
0.400
R0.375
NOTES:
1. CBORE DIAMETER: 0.438"
CBORE DEPTH: 0.40"
CSINK .385 dia x 100 deg
0.201" dia THRU
2 PLACES
Entire piece anodized!
UNLESS OTHERWISE SPECIFIED:
NAME
DATE
DRAWN
AEG
1 Aug 06
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
MATERIAL
AL 6061-T6
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
AIR FORCE INSTITUTE OF TECHNOLOGY
TITLE:
PRESSURE TRANSDUCER MOUNTING BLOCK (PIECE 2)
SIZE
A
DWG. NO.
RIGEX-2006-19-1
REV
C
SCALE: 1.5:1
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1

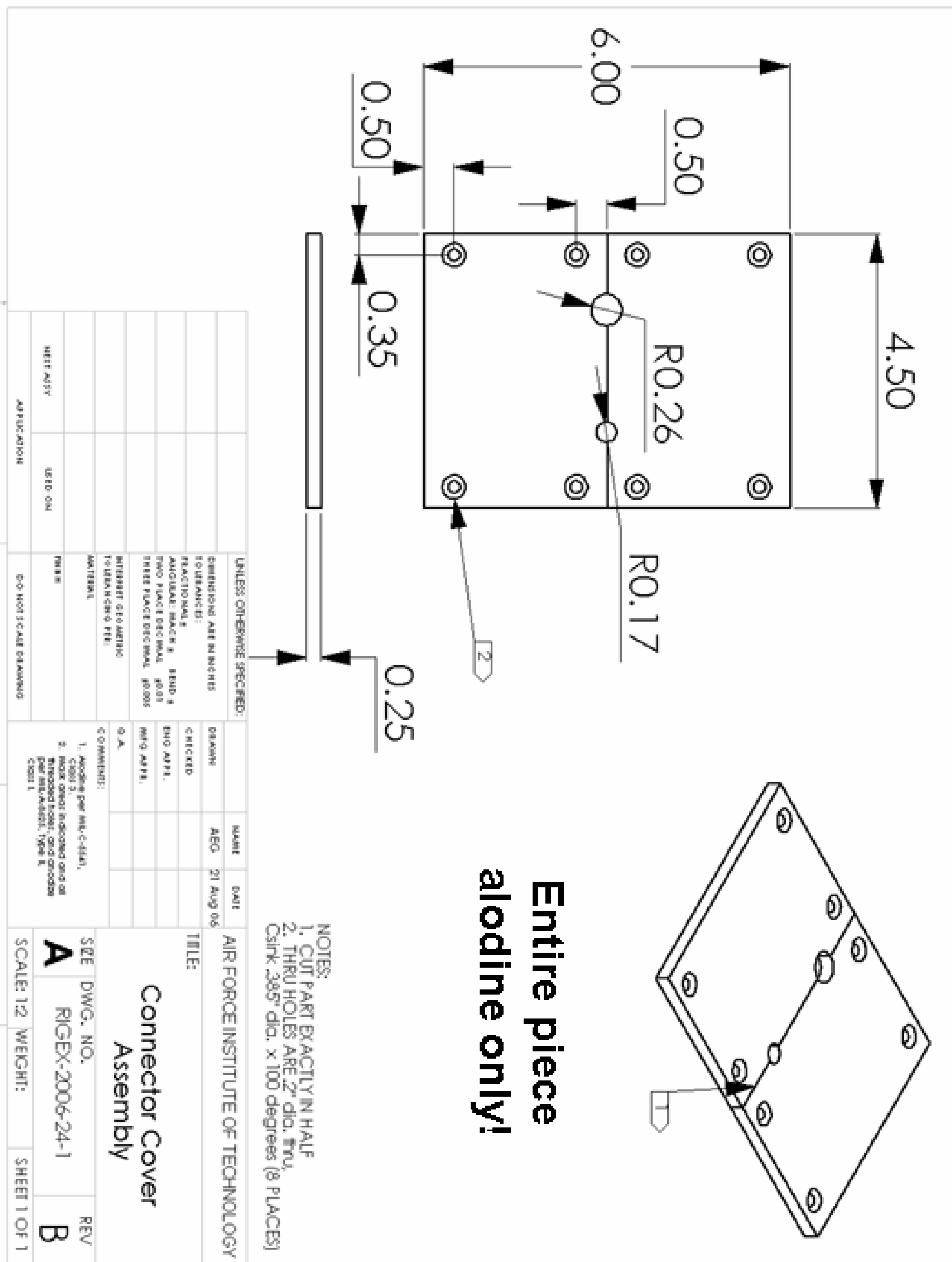

2.50
0.375
0.375
1.50
0.75
R0.375
1.25
0.75
Ø0.385
1
Entire piece anodized!
NOTE:
1. THRU HOLE .1935 dia
CBORE .385 dia x .75 depth
2 PLACES.
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
AL 6061-T6
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
AEG
1 Aug 06
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
AIR FORCE INSTITUTE OF TECHNOLOGY
TITLE:
PRESSURE TRANSDUCER MOUNT #2 - PIECE 1
SIZE
A
DWG. NO.
RIGEX-2006-21-1
REV
B
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1



2.50
1.25
1.50
0.75
0.50
0.875
R0.375
1.25
Entire piece anodized!
NOTE:
ALL HOLES DIMENSIONED ON THIS SHEET ARE TAPPED #10-32 UNJ, DEPTH: 0.5"
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
AL 6061-T6
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
AEG
1 Aug 06
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1. Alodine per MIL-C-5541, Class 3.
2. Mask areas indicated and all threaded holes, and anodize per MIL-A-8625, Type II, Class I.
AIR FORCE INSTITUTE OF TECHNOLOGY
TITLE:
PRESSURE TRANSDUCER MOUNT #2 - PIECE 2
SIZE
A
DWG. NO.
RIGEX-2006-22-1
REV
A
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1


0.500
0.219
1.125
2
3
0.950
1.500
0.50
Entire piece anodized!
NOTES:
1. CBORE 0.27 dia X .80 DEPTH
THRU HOLE .129 dia
2 PLACES
2. TAPPED #10-32 UNJ HOLES, 2 PLACES
DEPTH: 0.54"
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
AL 6061-T6
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
AEG
1 Aug 06
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
AIR FORCE INSTITUTE OF TECHNOLOGY
TITLE:
SOLENOID MOUNTING BLOCK
SIZE
A
DWG. NO.
RIGEX-2006-20-1
REV
C
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1


Entire piece anodized!
NOTE:
1. 0.272" DIA. THRU
2. THRU: 0.201" dia. Csink .385" dia x 100 degrees [SAME PLACEMENT ON BOTH PIECES]
10.00
4.625
0.75
1.25
0.50
9.00
1.00
2.00
0.25
AL 6061-T6
AIR FORCE INSTITUTE OF TECHNOLOGY
TITLE:
Computer Mounting Plate
SIZE
A
DWG. NO.
RIGEX-2006-23-1
REV
D
SCALE: 1:3
WEIGHT:
SHEET 1 OF 1



6.00
0.50
0.50
0.35
4.50
R0.26
R0.17
0.25
Entire piece alodine only!
NOTES:
1. CUT PART EXACTLY IN HALF
2. THRU HOLES ARE .2" dia. thru,
Csink .385" dia. x 100 degrees (8 PLACES)
UNLESS OTHERWISE SPECIFIED:
NAME
DATE
DRAWN
AEG
21 Aug 06
CHECKED
AIR FORCE INSTITUTE OF TECHNOLOGY
TITLE:
Connector Cover Assembly
SIZE
A
DWG. NO.
RIGEX-2006-24-1
REV
B
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1

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Vita

Ensign Brady D. O'Neal attended Quince Orchard High School in Gaithersburg, MD and graduated from Framingham High School in Framingham, MA in June 2002. In June 2002, he entered undergraduate studies at the United States Naval Academy in Annapolis, MD. As a midshipman, ENS O'Neal was an active member of 18^{th} Company and the Navy SAE Formula car team. He graduated with a Bachelor of Science degree in Mechanical Engineering in May 2006. He was commissioned as a naval officer upon graduation from the U.S. Naval Academy.

ENS O'Neal's first assignment was to the Air Force Institute of Technology (AFIT) as part of the Immediate Graduate Education Program (IGEP) for Navy ensigns. In June 2006, he entered the Graduate School of Engineering and Management at AFIT to gain a Master's Degree in Aeronautical Engineering, concentrating on aerodynamics and air weapons. Upon graduation, he will be assigned to NAS Pensacola to begin flight training as a naval aviator.

REPORT DOCUMENTATION PAGE						*Form Approved* *OMB No. 074-0188*
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1. REPORT DATE *(DD-MM-YYYY)* 14 Jun 07			**2. REPORT TYPE** **Master's Thesis**			**3. DATES COVERED** *(From – To)* **Jun 2006– Jun 2007**
4. TITLE AND SUBTITLE Development and Testing of the Rigidizable Inflatable Get-Away-Special Experiment						**5a. CONTRACT NUMBER**
						5b. GRANT NUMBER
						5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) O'Neal, Brady D., Ensign, USN						**5d. PROJECT NUMBER**
						5e. TASK NUMBER
						5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S) Air Force Institute of Technology Graduate School of Engineering and Management (AFIT/EN) 2950 Hobson Way WPAFB OH 45433-7765						**8. PERFORMING ORGANIZATION REPORT NUMBER** **AFIT/GAE/ENY/07-J16**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) NA						**10. SPONSOR/MONITOR'S ACRONYM(S)**
						11. SPONSOR/MONITOR'S REPORT NUMBER(S)
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13. SUPPLEMENTARY NOTES						
14. ABSTRACT The purpose of this research project is to develop the Rigidizable Inflatable Get-Away-Special Experiment (RIGEX) from a computer-based model into a space-qualified prototype. Past research projects have developed RIGEX's command and control, structural analysis, and integration with the orbiter. This thesis details the organization, assembly, and test planning for the RIGEX protoflight model. Strict requirements imposed by the National Aeronautics and Space Administration (NASA) must be fulfilled for any payload to travel into space. Based on the requirements set forth by NASA documentation, this thesis establishes appropriate assembly procedures for the construction of a space payload. Detailed design changes are described, as well as any problems encountered during assembly. Various lessons learned throughout the course of this project are discussed.						
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